BTeV Ring Imaging Cherenkov Detector (WBS 1.3)

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Outline

- Introduction and overview of the BTeV Ring Imaging Cherenkov Detector (RICH)

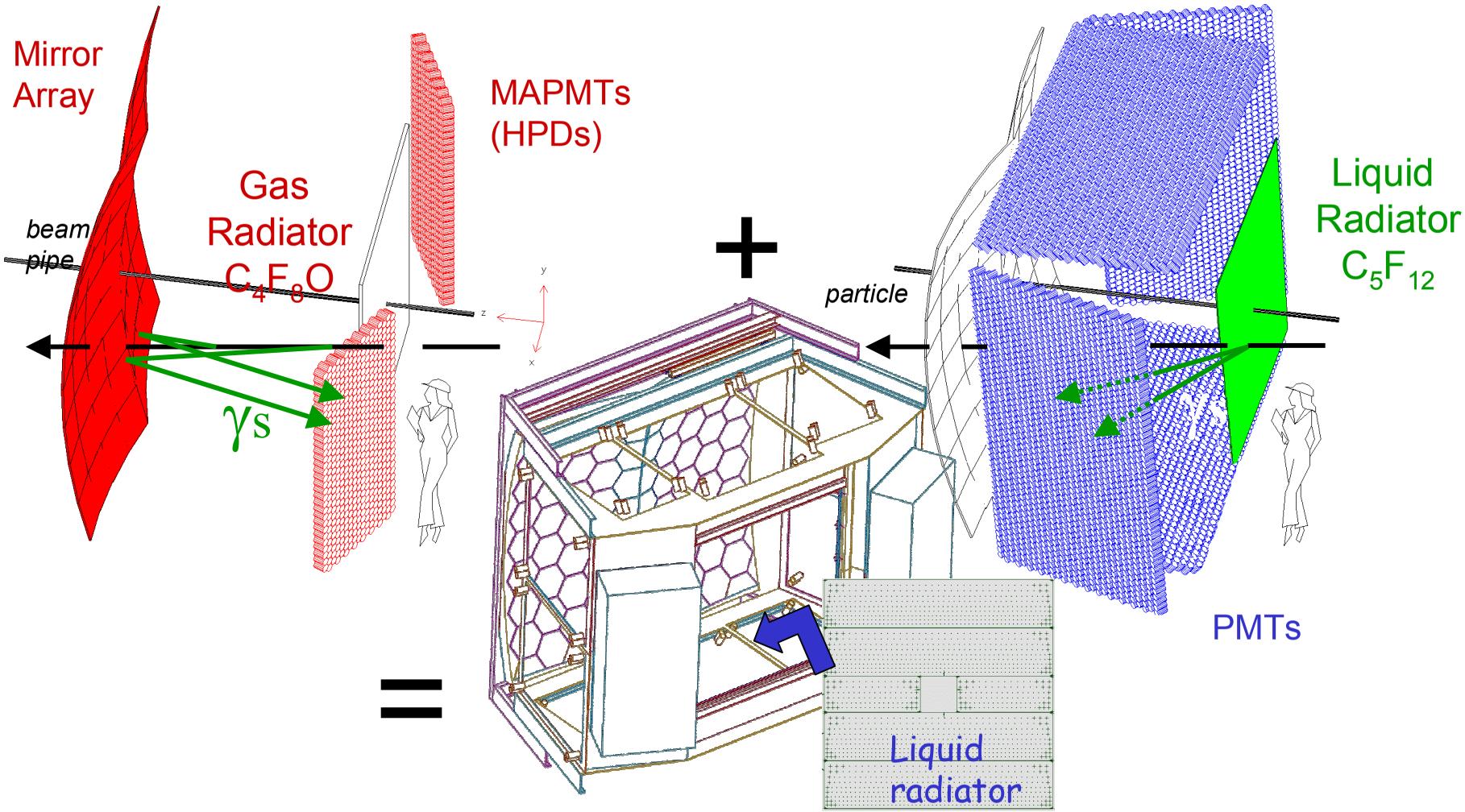
- WBS 1.3 – RICH
  - Project requirements and description
  - Project organization
  - Cost, Schedule and Critical Path
  - Milestones
  - Responses to DOE CD1 Recommendations

- Presentations prepared for the breakout sessions
- Conclusions
- Glossary

The BTeV RICH Components

Mirror Focused Gas Radiator RICH

Proximity Focused Liquid RadiatorRICH

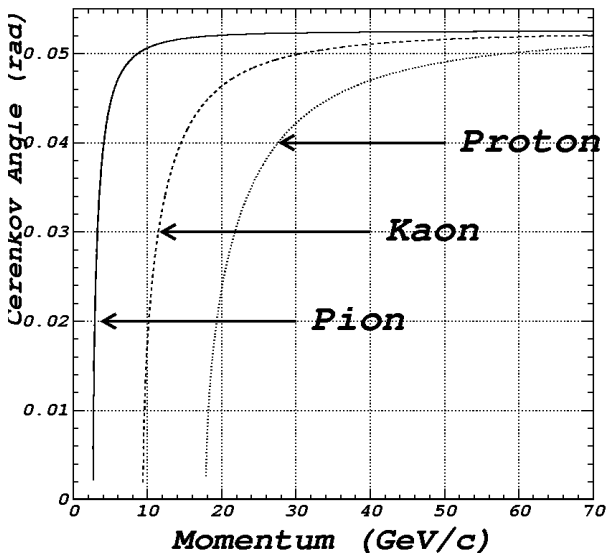


BTeV RICH: A good match to our physics goals

Gas

C_4F_8O

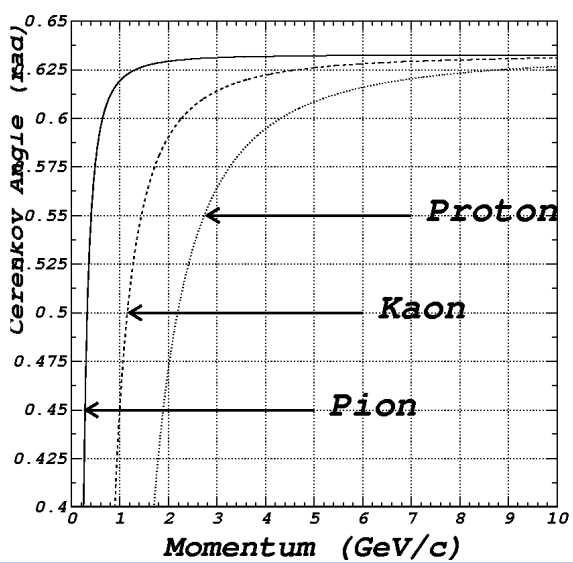
n=1.00138



Liquid

C_5F_{12}

n=1.29

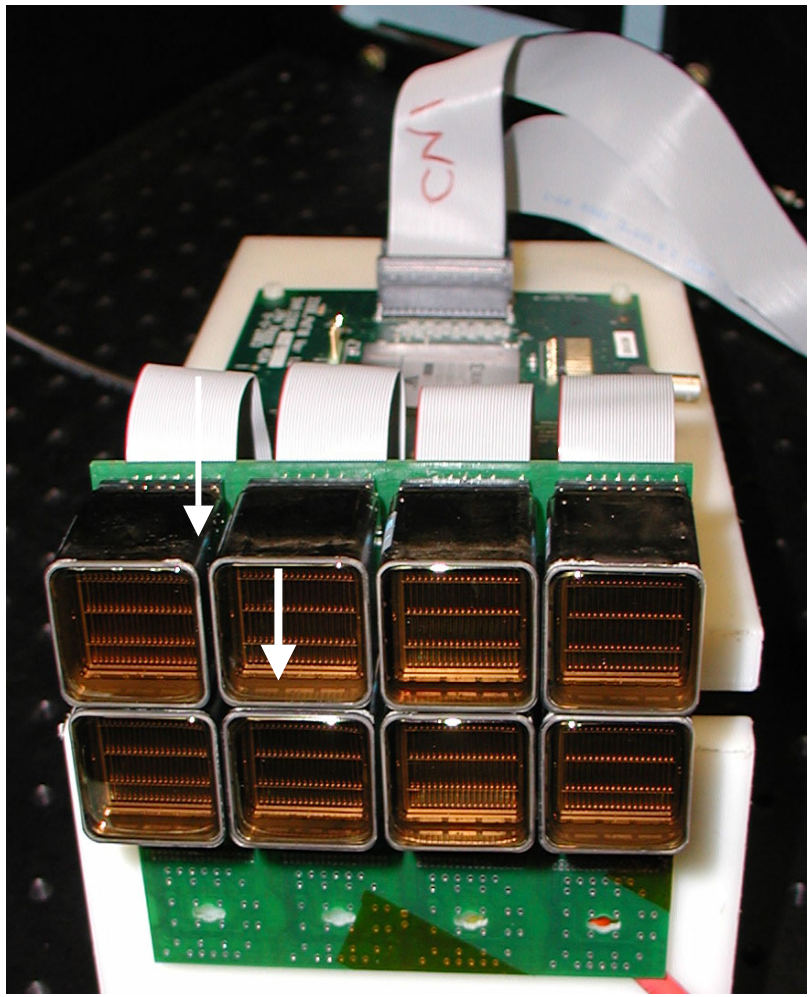


- The combination of gas and liquid radiator RICH achieve the desired particle species separation over the whole momentum range of interest:
  - The gas radiator RICH provides good hadron separation up to 70 GeV/c
  - The liquid radiator RICH provides p/K separation below 9.5 Gev/c.
  - The RICH detector provides μ ID up to 17 GeV/c and electron ID up to 23 GeV/c over the full solid angle coverage of the BTeV tracking system.

The RICH Detector Sub-systems

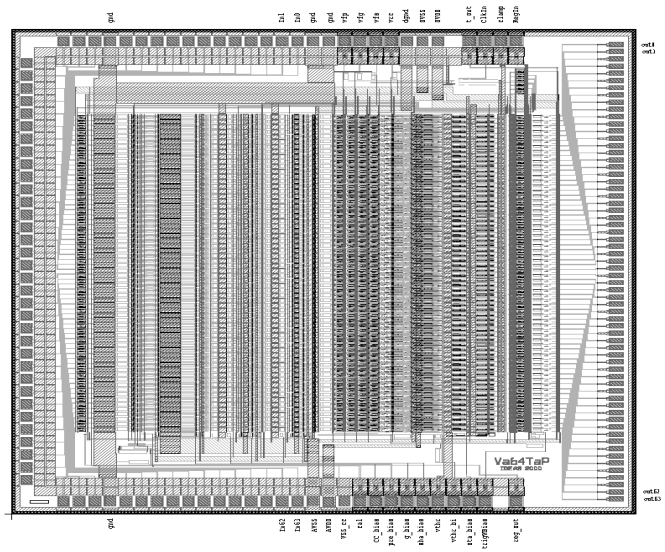
- The photon detectors for the GAS RICH
  - Baseline is 16 channel Hamamatsu MAPMTs with DEP 163 channel HPDs as viable alternative
- The photon detectors for the LIQUID RICH
  - 3" PMTs (off-shelf products of Hamamatsu, Burle, Photonics and ElectronTubes)
- The front end electronics
  - Front end hybrids developed in collaboration with IDEAS, NO and front end multiplexer boards developed at Syracuse University
- The mirror
  - Light-weight mirror made up of multiple tiles, CMA, Tucson, AZ baseline solution, several alternative options
- The mechanical structure (a superstructure where all the various components are assembled in a staged installation)
- High voltage, low voltage and cooling infrastructure (1KV HV+ low noise ±5V system).

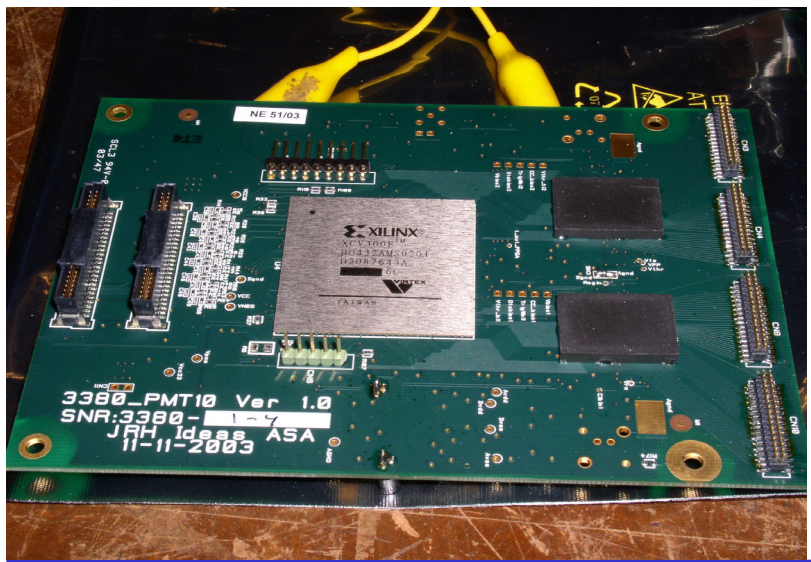
Gas Radiator Photon Detectors



- Baseline solution: 16 channel Hamamatsu R8900-00-M16 MaPMTs (9016 devices for 2 arrays)
- Main features:
  - **Predicted σ_{track} ~0.115 mr**
  - **Predicted N_γ ~52**
  - QE*CE 13-15%
  - Active area: 85%
  - **6x6 mm pixel size well suited for BTeV**
  - Gain [1-4x10^6]
  - HV 600-900 V (negative)
  - Standing current in voltage divider 340 μA
- Alternative solution 163 pixel HPD from DEP, presently more expensive

Photon detector electronics





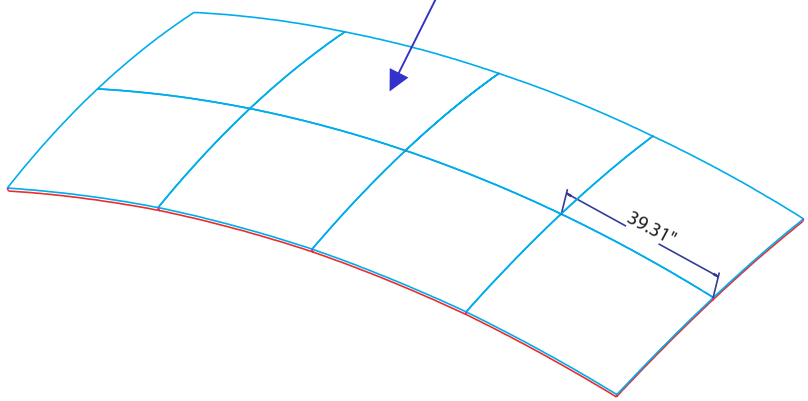
- FRONT END ASIC must
  - Low noise (~1000 e^-)
  - On chip sparsification
  - High Dynamic range
  - Parallel digital readout to allow event synchronization
- PROTOTYPING STEPS implemented:
  - VA_BTeV1 [for HPD readout: low noise (500e^- ENC), discriminator not optimized for high counting rates] & Va+BTeV1.1 [improved discriminator and 1 analog test channel]

  VA_MaPMT [for MAPMT, improved discriminator, 1 analog test channel]
  - In progress: optimization of dynamic range for MaPMT applications and of noise versus C_{in} for PMT applications

The RICH Mirror System

- Two large mirrors, each one has 200cm (width) and 400cm (height). They can be broken down to any number of mirrors of any shape, so that cost and performance are optimized.
- A half circle hole in the side (of radius ~3 cm).
- Mean radius is fixed to 697cm.
- 1-2% radiation length
- CMA approach: each mirror made up of 8 square tiles

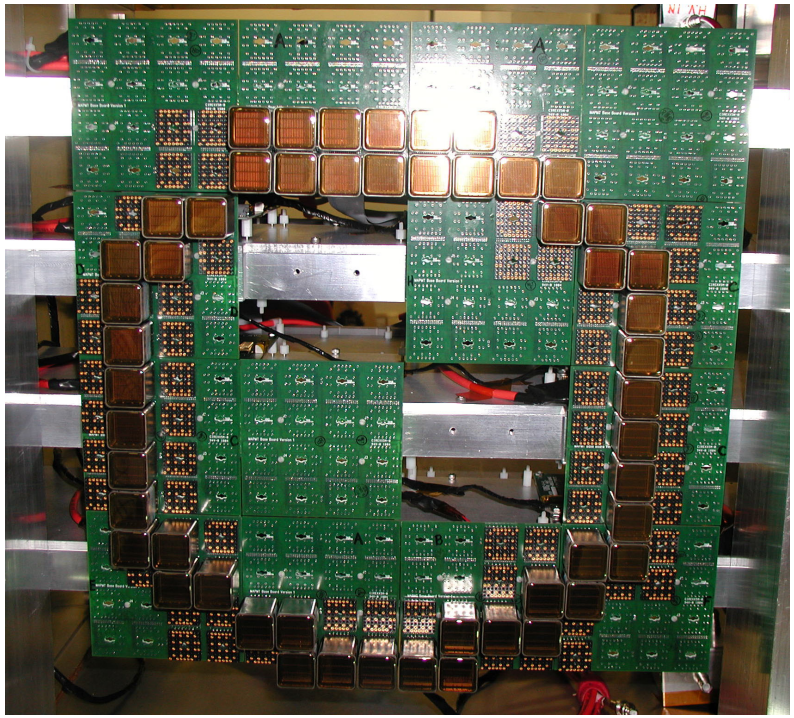
½ of RICH mirror based on CMA segment design

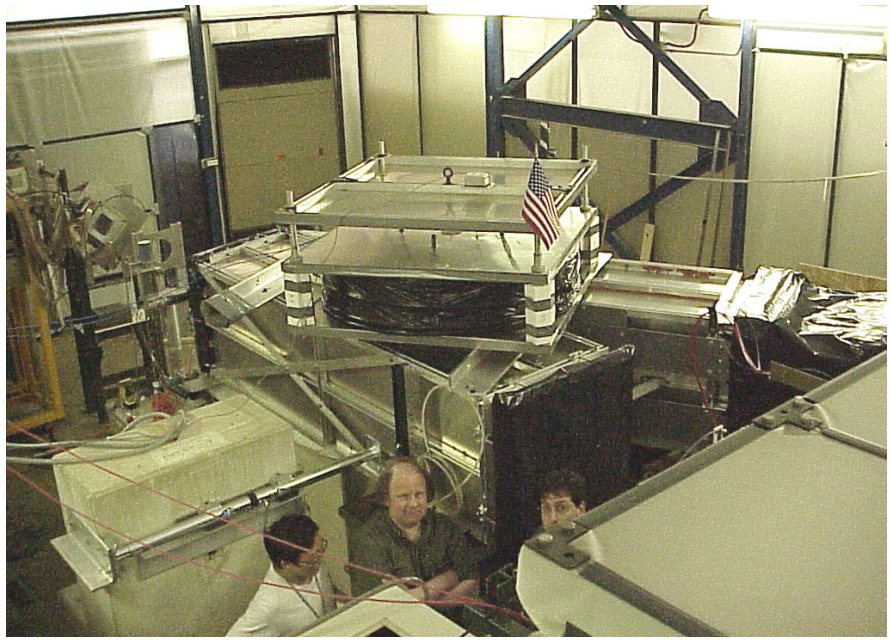


Example of CMA PROJECTS

•CMA provided competitive quote & demonstrated capabilities beyond our needs (optical properties controlled to fraction of a wave)

C_4F_8O radiator test beam studies

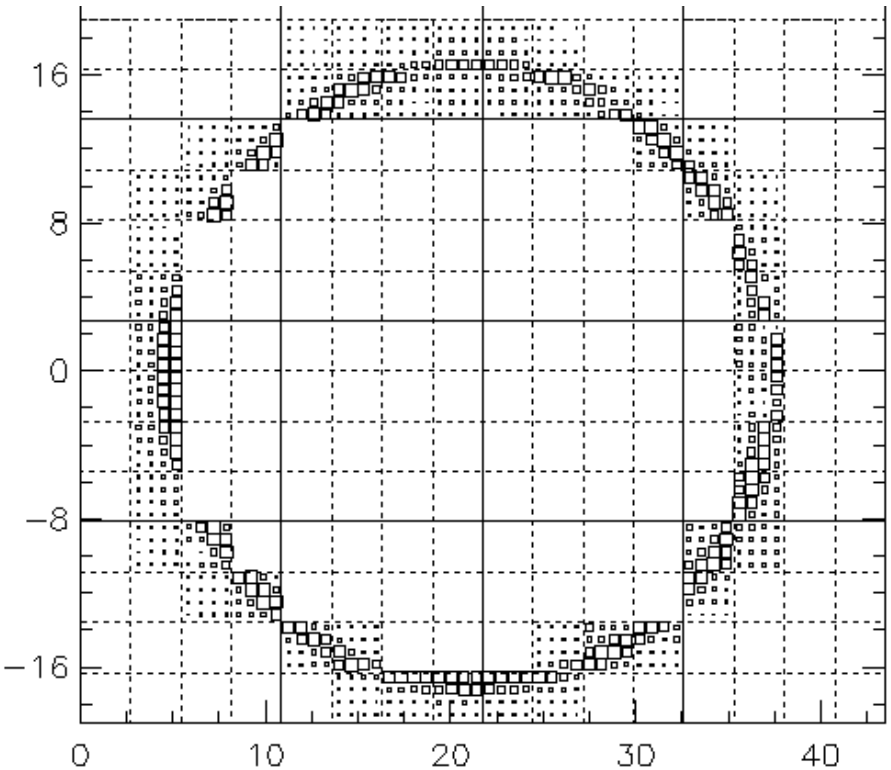




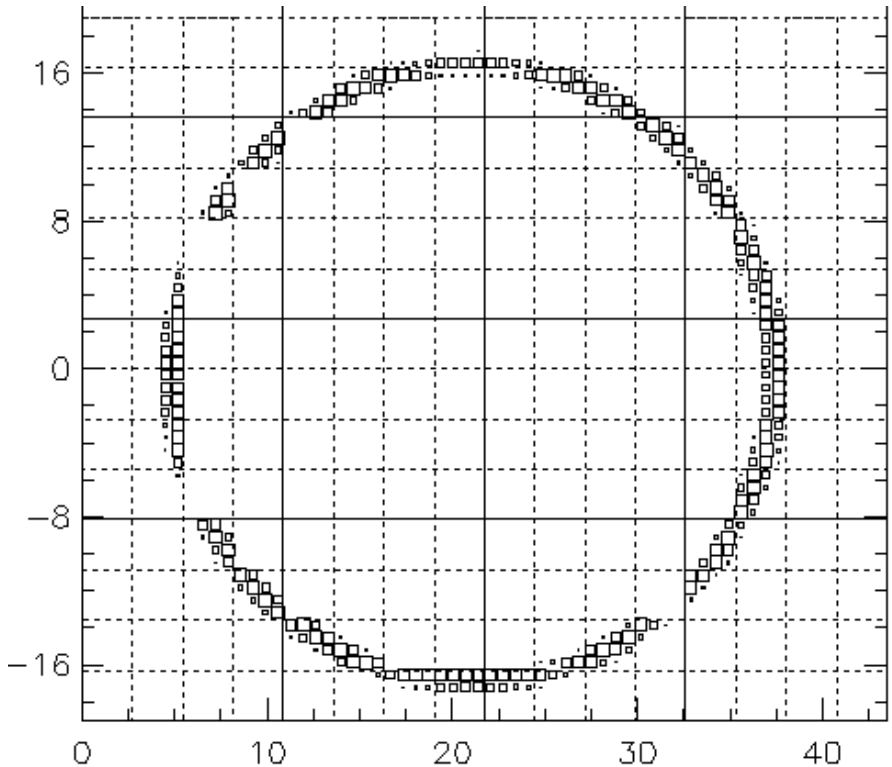
- All 52 MAPMTs deployed and read out with prototype front end electronics designed for our applications

Example of data versus MC comparison

data



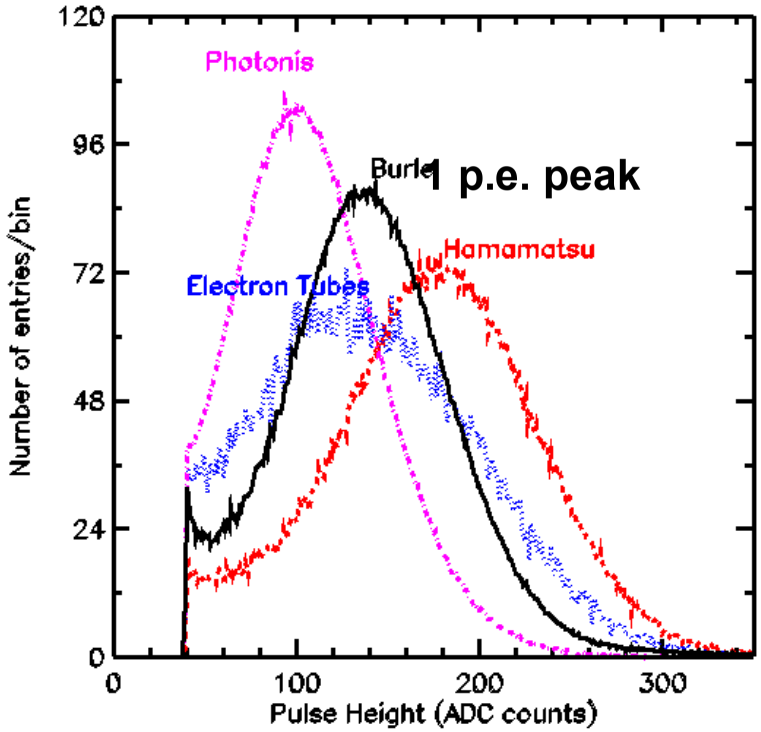
MC



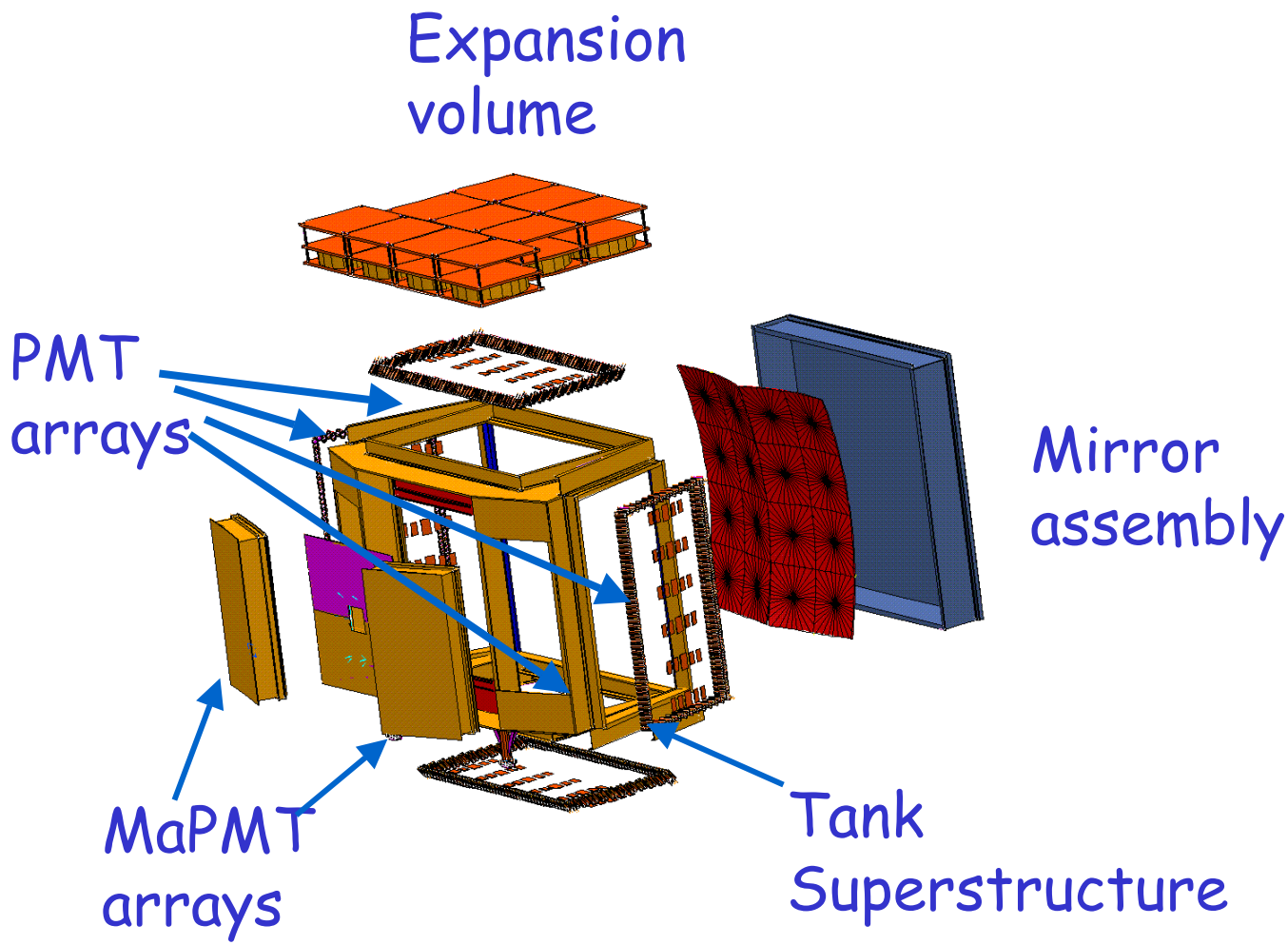
MC predictions in agreement with the data

Photodetectors for the Liquid Radiator RICH

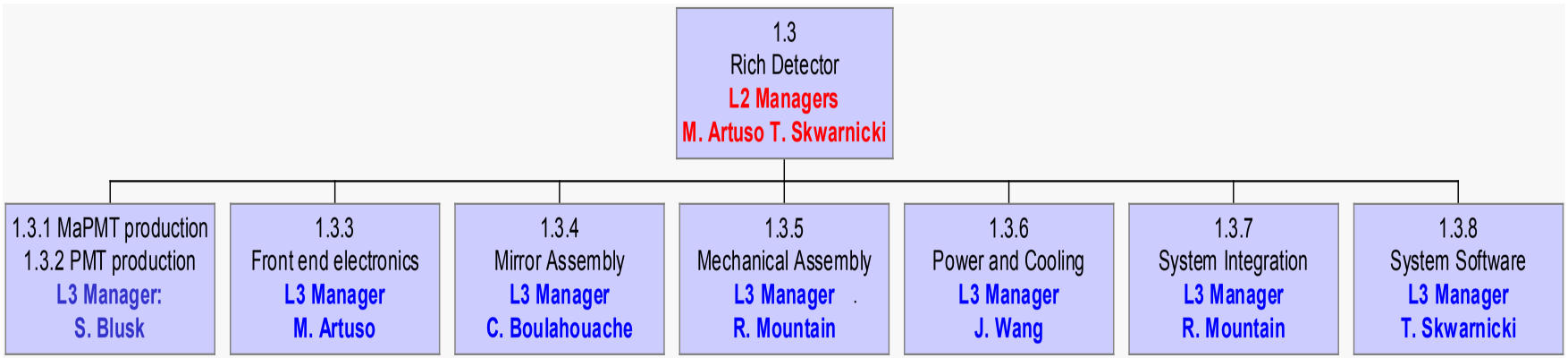
- Standard (single anode) 3" PMT:
  - Need about 5,000 tubes
  - 8-stage box dynode structure; gain ~10^5
  - Produced in mass quantities for medical applications
- We tested sample tubes from 4 manufacturers:
  - Burle, Electron Tubes, Photonics and Hamamatsu
  - All capable of detecting a single photon
  - Magnetic field sensitivity was determined (OK when shielded by mumetal tubes)



The RICH Vessel Superstructure



Project Organization WBS 1.3



Base cost: 12.1 M$, (Material 9.9 M$, Labor 2.2 M$) + NSF support for R&D work (unchanged from CD1 review)

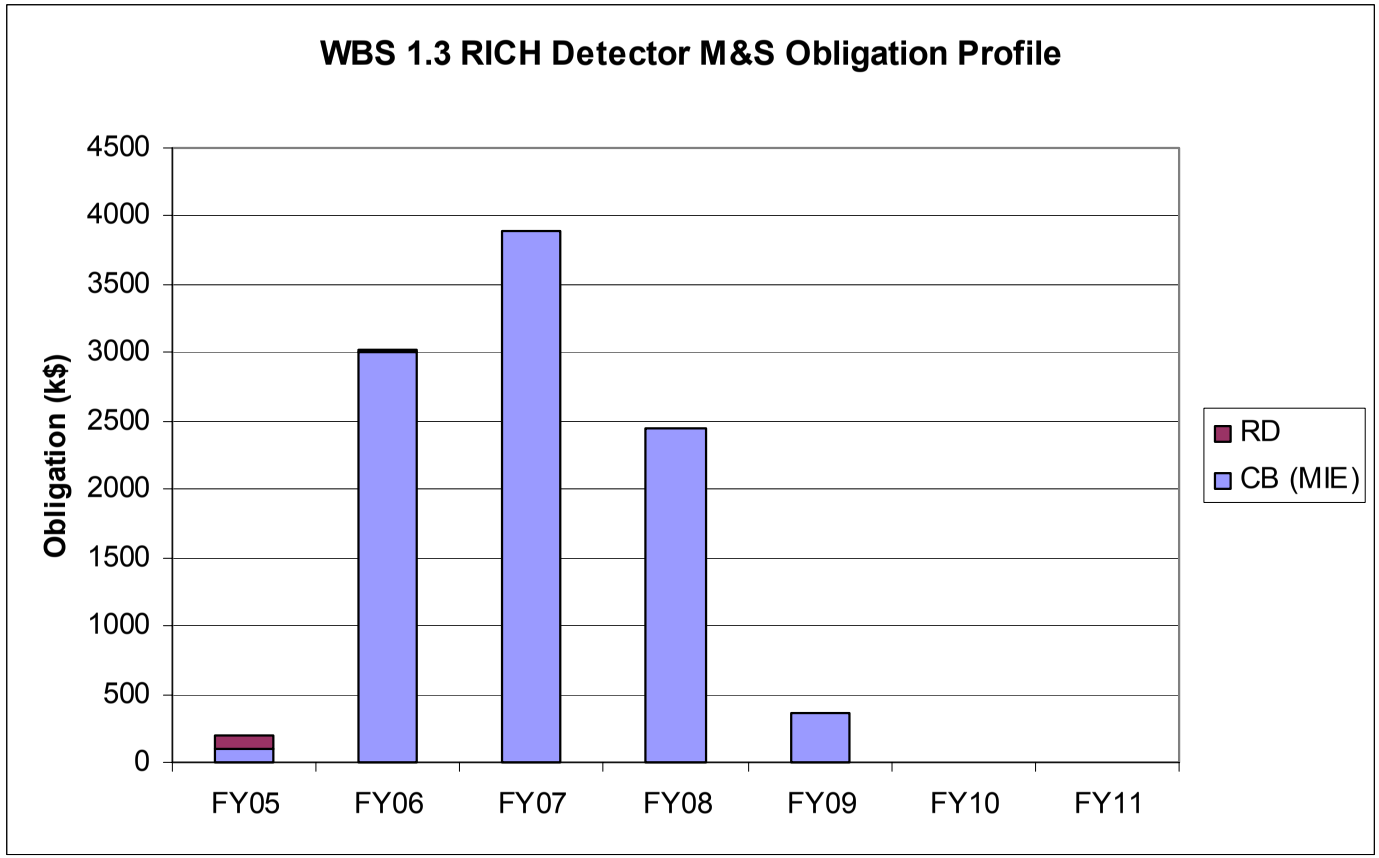
Construction Cost

WBS 1.3

Activity ID	Activity Name	Base Cost ($)	Material Contingency (%)	Labor Contingency (%)	Total FY05	Total FY06	Total FY07	Total FY08	Total FY09	Total FY10	Total FY05-10
1.3.1	Multi-anode PMT Photon Detectors (MAPMTs)	5,461,375	39	31	65,863	1,974,017	3,658,062	1,911,152	1,118	0	7,610,213
1.3.2	Photomultiplier Tubes (PMTs)	1,161,277	25	24	0	203,098	306,716	677,752	264,029	0	1,451,595
1.3.3	Photon Detector Electronics	1,659,190	44	43	131,558	1,115,022	1,138,293	0	0	0	2,384,873
1.3.4	Mirror Arrays	792,604	53	32	29,133	925,493	212,578	1,908	0	0	1,169,112
1.3.5	Mech Gas Liquid & Related Systs	1,436,859	28	29	63,128	317,781	875,858	93,356	494,430	0	1,844,554
1.3.6	Power Monit Cooling & Related Systs	783,141	25	20	9,171	1,374	60,308	866,553	33,962	0	971,368
1.3.7	RICH Detector Install & Integ & Test	394,595	21	28	109,381	33,594	303,977	45,173	4,661	0	496,786
1.3.8	RICH Detector SW	188,110	44	33	0	0	56,275	190,178	6,754	0	253,206
1.3.9	RICH Detector Subproject Management	250,317	20	20	53,303	112,071	49,479	26,099	52,080	7,349	300,380
1.3	file_13s_21sep04	12,127,468	37	29	461,538	4,682,449	6,661,545	3,812,171	857,036	7,349	16,482,087

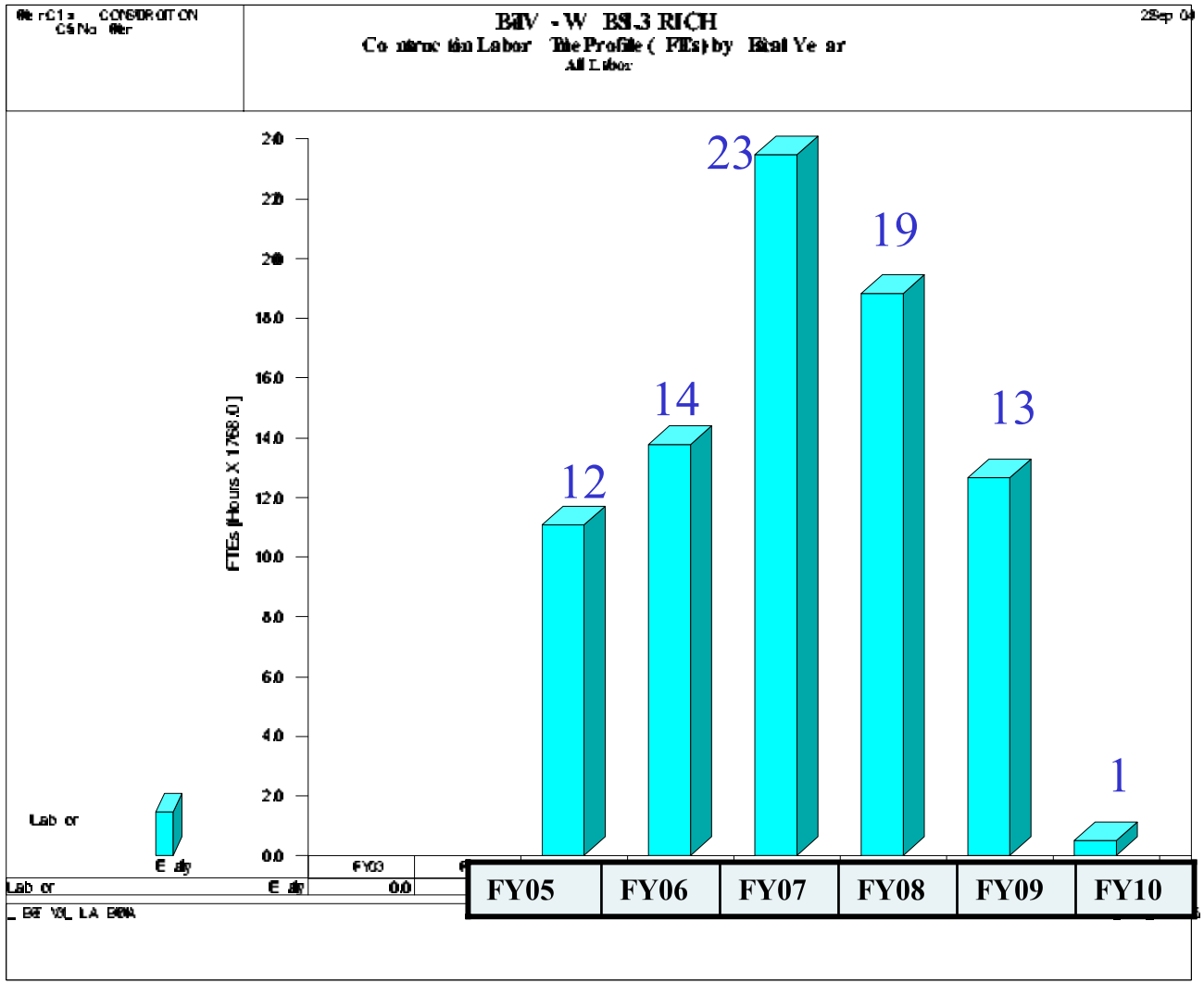
unchanged from CD1 review

M&S Cost Profile by Fiscal Year WBS 1.3

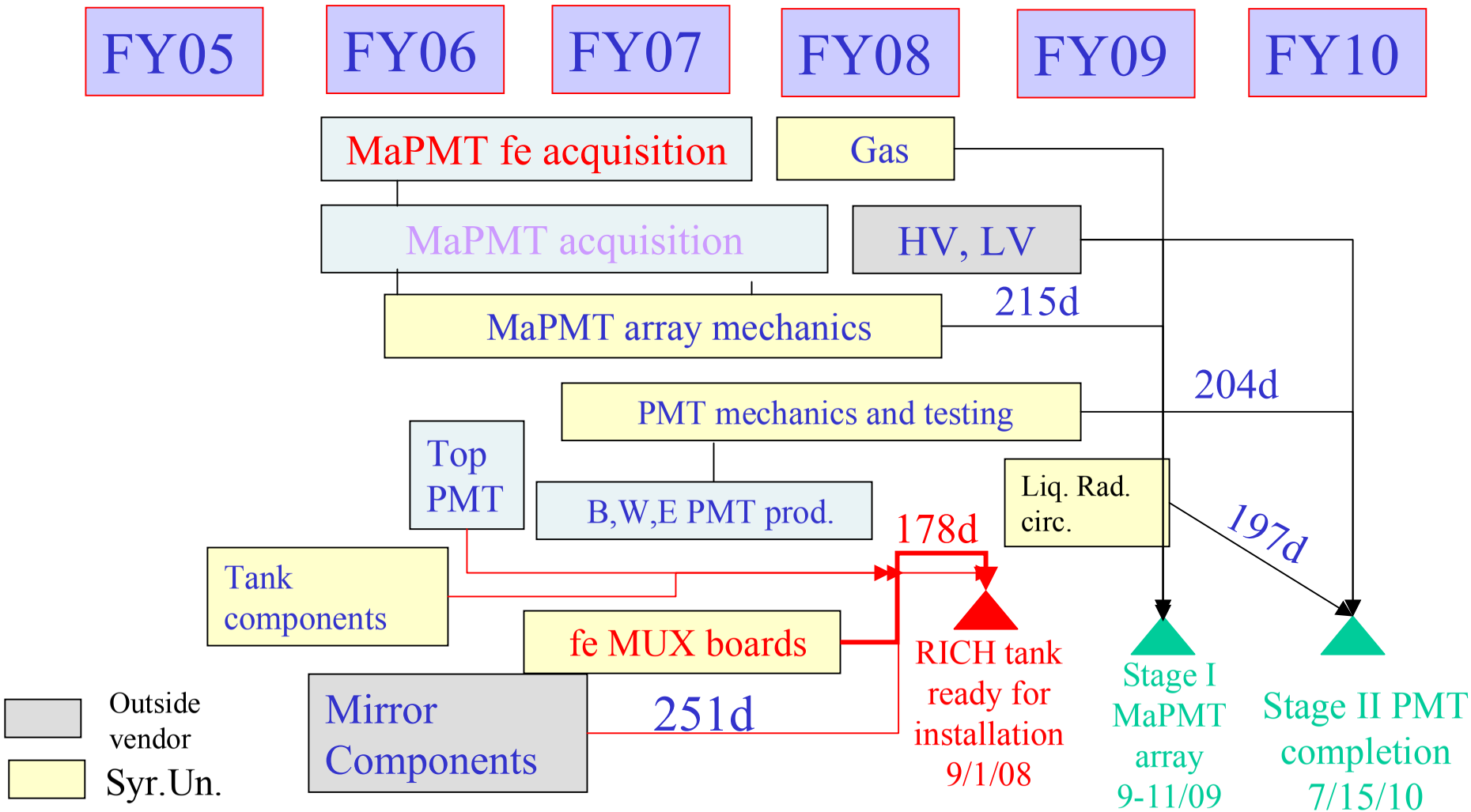


	FY05	FY06	FY07	FY08	FY09	FY10
CB (MIE)	96	3005	3890	2455	360	
RD	106	20				

Labor Profile by Fiscal Year WBS 1.3



Description of Project Flow WBS 1.3



Critical Path Analysis Without Distributed Floats WBS 1.3

- Partially instrumented RICH tank ready to roll into collision hall (TF = 178d days)
  - The latest component to arrive is the multiplexer board that needs to be designed in parallel with DCB board (DAQ-WBS 1.9).
  - Other important tasks that affect this milestone are TOP PMT array implementation (TF=232 d) and mirror procurement (TF=251d).
- MaPMT Array Installation (TF = 215 days)
  - MaPMT procurement completed in FY07. The assembly and test schedule are closely integrated to optimize the completion time.
- PMT final installation (TF = 197 days)
  - The float is determined by the present planned time for the completion of the liquid radiator fluid circulation and monitoring systems. The PMT acquisition and testing has comparable robustness (TF=204 days).

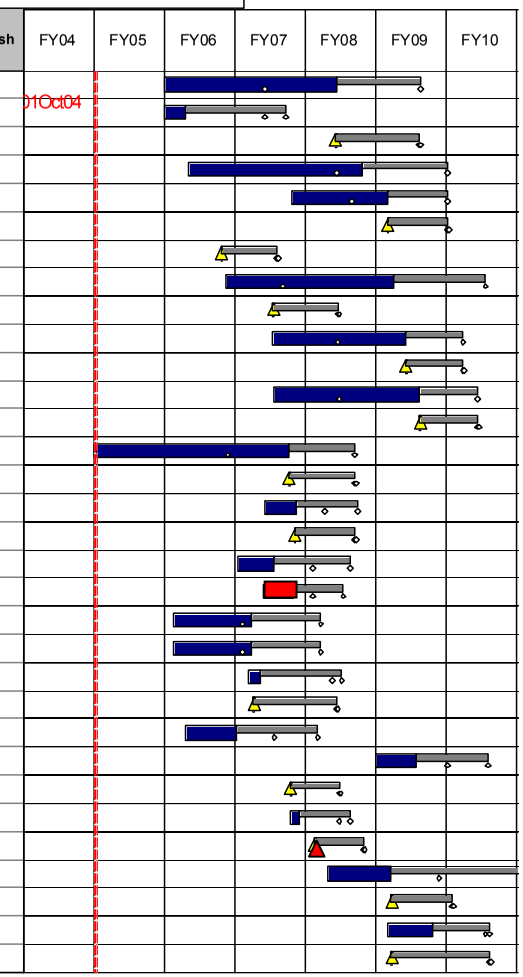
Critical Path Analysis Gantt Chart WBS 1.3

WBS 1.3

RICH Detector

Critical path

Activity ID	Activity Desc.	Total Float	Early Start	Early Finish
1.1.3	MAPMT Fabrication	306d	03Oct05	11Mar08
1.1.3.1.2	Fab 1st batch of MAPMTs	362d	03Oct05	24Jan06
1.1.3.5.4	T5M: Received Del of 100% of MAPMTs at SU	306d	05Mar08	05Mar08
1.1.4	MAPMT Prod QA Test (Accept Test)	306d	08Feb06	23Jul08
1.1.5	MAPMT Prod Long-Term Tests, Certification& Storage	215d	26Jul07	02Dec08
1.1.5.5.5	T4M: 100% MAPMT delivered and tested	215d	02Dec08	02Dec08
2.3.1.7	T5M: PMTs Apprvd for Prod	204d	21Jul06	21Jul06
2.3.3	PMT Prod Fab	204d	21Aug06	07Jan09
2.3.3.1.5	T5M: Received Del of 1st batch of PMTs at SU	232d	17Apr07	17Apr07
2.3.4	PMT Prod QA Test (Accept Test)	204d	17Apr07	09Mar09
2.3.4.4.5	T5M: Apprvd 100% of PMT Prod (passed QA tests)	204d	09Mar09	09Mar09
2.3.5	PMT Prod Long-Term Test (Certification) & Storage	204d	23Apr07	18May09
2.3.5.4.4	T4M: 100% PMT received and tested	204d	18May09	18May09
3.1.2	MAPMT Hybrid Prod - Syracuse	235d	01Oct04	11Jul07
3.1.2.4.1.9	T4M: 100% MAPMT hybrids certified	235d	11Jul07	11Jul07
3.1.4	MAPMT Front End Multiplexer board production	215d	05Mar07	21Aug07
3.1.4.9	T4M: MAPMT front end multiplexer boards produced	215d	08Aug07	08Aug07
3.2.2	PMT Hybrid Prod	272d	16Oct06	25Apr07
3.2.4	PMT front end multiplexer board Prod	178d	01Mar07	02Aug07
4.2.2	Mirror-Segment Prod Fab	251d	14Nov05	27Dec06
4.2.2.1	Fab & Del of Prod Mirror-Segments	251d	14Nov05	27Dec06
4.3.2	QA Test of Prod Mirror-Segments - 2nd batch	296d	13Dec06	09Feb07
4.3.2.5	T4M: Mirror segment constr completed	296d	04Jan07	04Jan07
4.5.6	Mirror Mech Mounting (Panels) - Syracuse	295d	25Jan06	09Oct06
5.2.2	Liquid Radiator Prod	260d	01Oct08	01May09
5.3.5.3.7	T5M: Top PMT beehive assembled	178d	12Jul07	12Jul07
5.3.7.1.3	Assemble PMTs on top beehive	178d	13Jul07	07Sep07
7.5.2.14	Lk4M: Instrumented tank ready to be transf. in collision hall	176d	15Nov07	15Nov07
7.6.2	MAPMT Testing and Inst. Syracuse	215d	28Jan08	23Dec08
7.6.2.5.4	T4M: East MAPMT array ready to be installed	215d	23Dec08	23Dec08
7.6.3	PMT Installation SYR	204d	02Dec08	22Jul09
7.6.3.4	T4M: PMT Array ready to be transferred into collision hall	349d	22Dec08	22Dec08



Key Milestones with distributed floats WBS 1.3

Milestone	Date
T3M-21:Mirror segment constr. completed	23 Mar, 2007
T2M-6: RICH Tank installed in C0	1 Aug, 2008
T2M-6 MaPMT PO Awarded	3 Oct, 2005
T3M-17: Start MaPMT prod	4 Jan, 2006
T3M-18: All MaPMT Delivered	5 May, 2008
T3M-19: MaPMT Hyb. Prod. Started	22 Feb, 2006
T3M-20: MaPMT hyb. Production completed	4 Jan, 2007
T3M-22: RICH Detector completely ready for installation at C0	24 Mar, 2009
T3M-23: Liquid Radiator PMTs proc. completed	7 Jan, 2009
T3M-24: Liquid Radiator assembly completed	22 Jul, 2009

Need by date 2 Nov, 2009

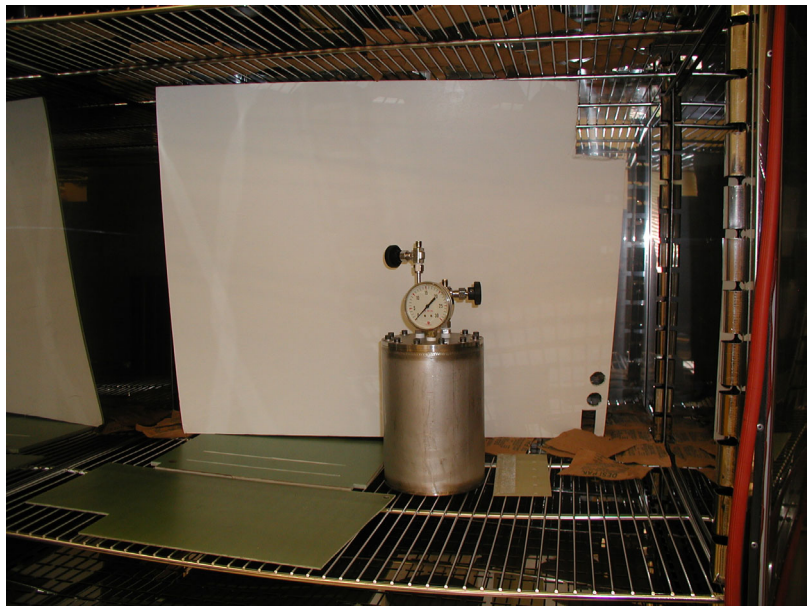
Need by date 17, May 2010

Responses to CD1 recommendations

- Recommendations:
  - Test prototype detectors in C0 asap to gain experience in a hadron collider
  - Measure neutron flux in various locations in C0
  - Study compatibility test between C_4F_8O and materials in the vessel

- Response:
  - We can take data in C0 with the LR prototype that will be used in the beam test of FY05 and do more extensive background studies
  - We have a material compatibility tests under way

Material Compatibility test (in progress)



- Vessel containing gas and material under test will be maintained in an oven at 70° C and changes will be assessed on a weekly basis
  - UVT acrylic
  - G-10 board
  - Mirror material
  - Rubber O-ring material
  - Epoxies : Armstrong Hysol Araldite…
  - Al, Construction steel, copper tubing, brass polyflow fitting
  - Teflon , Kevlar, carbon fiber
- Mechanical and optical properties will be assessed on a weekly basis
- Mirror optical properties when operating in gas environment

Summary

More information on the RICH detector project is available in the breakout sessions.

- Cost and Schedule Overview – Marina Artuso
- Photon detectors – Tomasz Skwarnicki
- MaPMT test beam results – Tomasz Skwarnicki
- Mirror design and testing – Tomasz Skwarnicki
- Mechanical design overview – Herman Cease

The End

Glossary of Terms

- MAPMT module: 32 MAPMT units mounted on a HV base board [HV connector + voltage dividers]
- MAPMT channel: support structure for 1 row of 49x4 MAPMTs
- PMT module: single PMT in injection mold ready for assembly in PMT beehive
- PMT beehive: PMT array support structure and B-field shield made up of mu-metal cylinders glued together
- FE electronics: Front End Hybrids [mixed-analog-digital front end circuitry] + Front end MUX [x4 multiplexer boards connected with remote data combiner boards]

Key Milestones without distributed floats

Milestone	Date
T3M-21:Mirror segment constr. completed	27 Dec, 2006
T2M-6: RICH Tank installed in C0	1 Aug, 2008
T2M-6 MaPMT PO Awarded	3 Oct, 2005
T3M-17: Start MaPMT prod	3 Oct, 2005
T3M-18: All MaPMT Delivered	5 Mar, 2008
T3M-19: MaPMT Hyb. Prod. Started	28Dec, 2005
T3M-20: MaPMT hyb. Production completed	3 Nov, 2006
T3M-22: RICH Detector completely ready for installation at C0	23 Dec, 2008
T3M-23: Liquid Radiator PMTs proc. completed	7 Jan, 2009
T3M-24: Liquid Radiator assembly completed	21 May, 2009

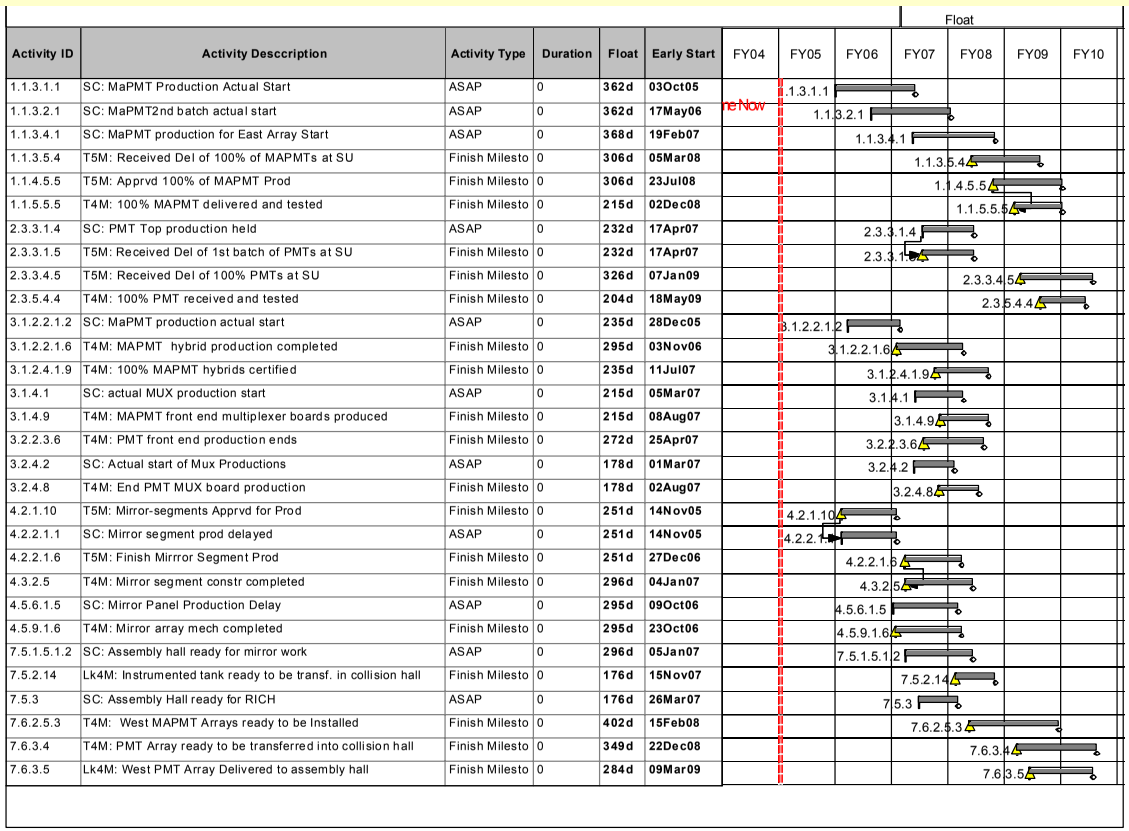
Need by date 2 Nov, 2009

Need by date 17, May 2010

Schedule Contingency WBS 1.3

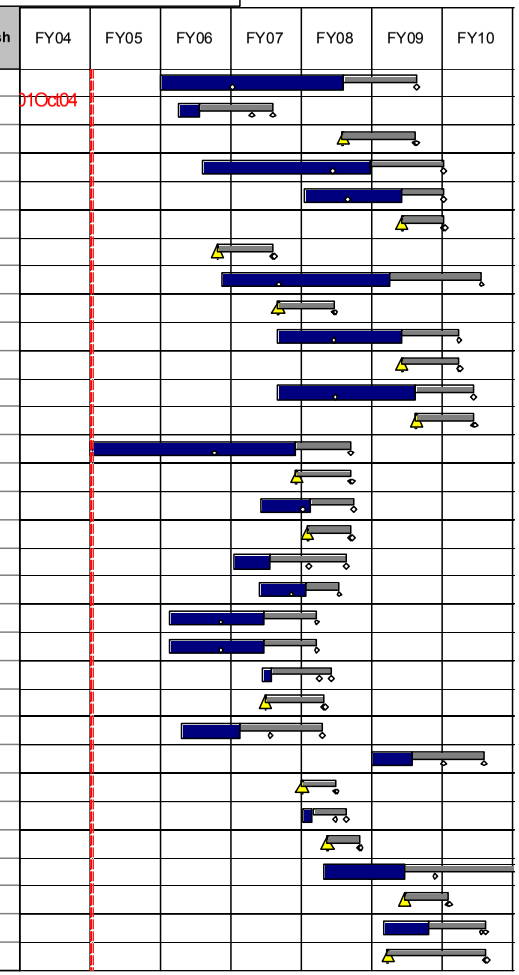
- Placed before key milestones or activities on critical or near critical path
- Nominally zero duration
- Distribute float throughout the duration of the project

Activity ID	Activity Desccription	Activity Type	Duration	Float	Early Start
1.1.3.1.1	SC: MaPMT Production Actual Start	ASAP	0	362d	03Oct05
1.1.3.2.1	SC: MaPMT2nd batch actual start	ASAP	0	362d	17May06
1.1.3.4.1	SC: MaPMT production for East Array Start	ASAP	0	368d	19Feb07
1.1.3.5.4	T5M: Received Del of 100% of MAPMTs at SU	Finish Milesto	0	306d	05Mar08
1.1.4.5.5	T5M: Apprvd 100% of MAPMT Prod	Finish Milesto	0	306d	23Jul08
1.1.5.5.5	T4M: 100% MAPMT delivered and tested	Finish Milesto	0	215d	02Dec08
2.3.3.1.4	SC: PMT Top production held	ASAP	0	232d	17Apr07
2.3.3.1.5	T5M: Received Del of 1st batch of PMTs at SU	Finish Milesto	0	232d	17Apr07
2.3.3.4.5	T5M: Received Del of 100% PMTs at SU	Finish Milesto	0	326d	07Jan09
2.3.5.4.4	T4M: 100% PMT received and tested	Finish Milesto	0	204d	18May09
3.1.2.2.1.2	SC: MaPMT production actual start	ASAP	0	235d	28Dec05
3.1.2.2.1.6	T4M: MAPMT hybrid production completed	Finish Milesto	0	295d	03Nov06
3.1.2.4.1.9	T4M: 100% MAPMT hybrids certified	Finish Milesto	0	235d	11Jul07
3.1.4.1	SC: actual MUX production start	ASAP	0	215d	05Mar07
3.1.4.9	T4M: MAPMT front end multiplexer boards produced	Finish Milesto	0	215d	08Aug07
3.2.2.3.6	T4M: PMT front end production ends	Finish Milesto	0	272d	25Apr07
3.2.4.2	SC: Actual start of Mux Productions	ASAP	0	178d	01Mar07
3.2.4.8	T4M: End PMT MUX board production	Finish Milesto	0	178d	02Aug07
4.2.1.10	T5M: Mirror-segments Apprvd for Prod	Finish Milesto	0	251d	14Nov05
4.2.2.1.1	SC: Mirror segment prod delayed	ASAP	0	251d	14Nov05
4.2.2.1.6	T5M: Finish Mirrror Segment Prod	Finish Milesto	0	251d	27Dec06
4.3.2.5	T4M: Mirror segment constr completed	Finish Milesto	0	296d	04Jan07
4.5.6.1.5	SC: Mirror Panel Production Delay	ASAP	0	295d	09Oct06
4.5.9.1.6	T4M: Mirror array mech completed	Finish Milesto	0	295d	23Oct06
7.5.1.5.1.2	SC: Assembly hall ready for mirror work	ASAP	0	296d	05Jan07
7.5.2.14	Lk4M: Instrumented tank ready to be transf. in collision hall	Finish Milesto	0	176d	15Nov07
7.5.3	SC: Assembly Hall ready for RICH	ASAP	0	176d	26Mar07
7.6.2.5.3	T4M: West MAPMT Arrays ready to be Installed	Finish Milesto	0	402d	15Feb08
7.6.3.4	T4M: PMT Array ready to be transferred into collision hall	Finish Milesto	0	349d	22Dec08
7.6.3.5	Lk4M: West PMT Array Delivered to assembly hall	Finish Milesto	0	284d	09Mar09



Gantt chart with distributed floats WBS 1.3

WBS 1.3

RICH Detector

Activity ID	Activity Desc.	Total Float	Early Start	Early Finish
1.1.3	MAPMT Fabrication	263d	03Oct05	09May08
1.1.3.1.2	Fab 1st batch of MAPMTs	263d	04Jan06	25Apr06
1.1.3.5.4	T5M: Received Del of 100% of MAPMTs at SU	263d	05May08	05May08
1.1.4	MAPMT Prod QA Test (Accept Test)	263d	10May06	23Sep08
1.1.5	MAPMT Prod Long-Term Tests, Certification& Storage	155d	19Oct07	03Mar09
1.1.5.5.5	T4M: 100% MAPMT delivered and tested	155d	03Mar09	03Mar09
2.3.1.7	T5M: PMTs Apprvd for Prod	202d	21Jul06	21Jul06
2.3.3	PMT Prod Fab	202d	21Aug06	07Jan09
2.3.3.1.5	T5M: Received Del of 1st batch of PMTs at SU	202d	29May07	29May07
2.3.4	PMT Prod QA Test (Accept Test)	202d	30May07	09Mar09
2.3.4.4.5	T5M: Apprvd 100% of PMT Prod (passed QA tests)	204d	09Mar09	09Mar09
2.3.5	PMT Prod Long-Term Test (Certification) & Storage	202d	05Jun07	18May09
2.3.5.4.4	T4M: 100% PMT received and tested	204d	18May09	18May09
3.1.2	MAPMT Hybrid Prod - Syracuse	195d	01Oct04	06Sep07
3.1.2.4.1.9	T4M: 100% MAPMT hybrids certified	195d	06Sep07	06Sep07
3.1.4	MAPMT Front End Multiplexer board production	155d	05Mar07	14Nov07
3.1.4.9	T4M: MAPMT front end multiplexer boards produced	155d	01Nov07	01Nov07
3.2.2	PMT Hybrid Prod	272d	16Oct06	25Apr07
3.2.4	PMT front end multiplexer board Prod	118d	01Mar07	26Oct07
4.2.2	Mirror-Segment Prod Fab	191d	14Nov05	23Mar07
4.2.2.1	Fab & Del of Prod Mirror-Segments	191d	14Nov05	23Mar07
4.3.2	QA Test of Prod Mirror-Segments - 2nd batch	206d	12Mar07	04May07
4.3.2.5	T4M: Mirror segment constr completed	206d	30Mar07	30Mar07
4.5.6	Mirror Mech Mounting (Panels) - Syracuse	295d	25Jan06	17Nov06
5.2.2	Liquid Radiator Prod	260d	01Oct08	01May09
5.3.5.3.7	T5M: Top PMT beehive assembled	118d	05Oct07	05Oct07
5.3.7.1.3	Assemble PMTs on top beehive	118d	08Oct07	04Dec07
7.5.2.14	Lk4M: Instrumented tank ready to be transf. in collision hall	118d	14Feb08	14Feb08
7.6.2	MAPMT Testing and Inst. Syracuse	155d	28Jan08	24Mar09
7.6.2.5.4	T4M: East MAPMT array ready to be installed	155d	24Mar09	24Mar09
7.6.3	PMT Installation SYR	204d	02Dec08	22Jul09
7.6.3.4	T4M: PMT Array ready to be transferred into collision hall	349d	22Dec08	22Dec08