# BTeV Ring Imaging Cherenkov Detector (WBS 1.3)

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# The BTeV RICH Group

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# Outline

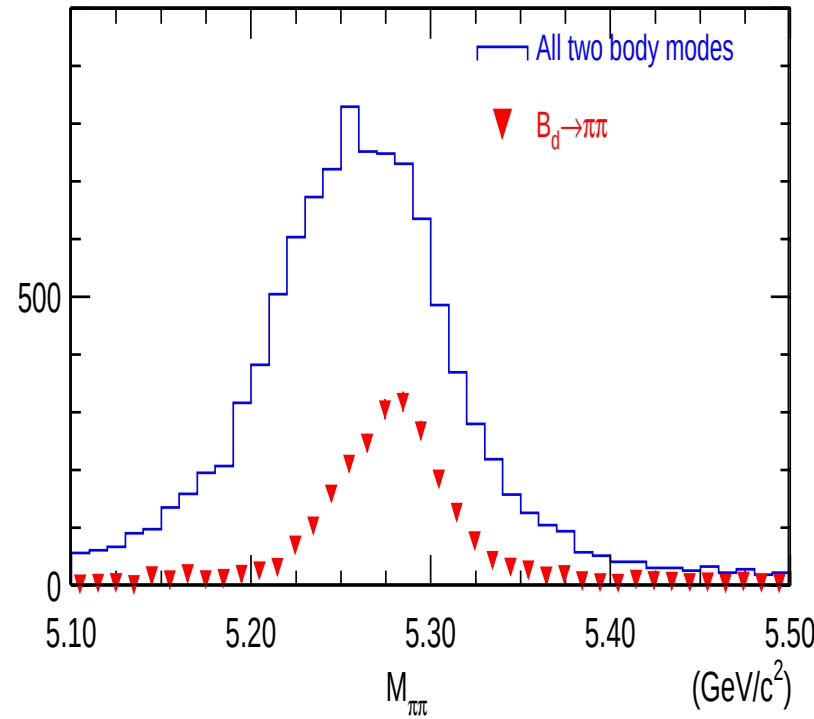
- Introduction and overview of the BTeV Ring Imaging Cherenkov Detector (RICH)

- WBS 1.3 – RICH
  - RICH Detector system
  - Project Management overview

- Presentations prepared for the breakout sessions

# Introduction

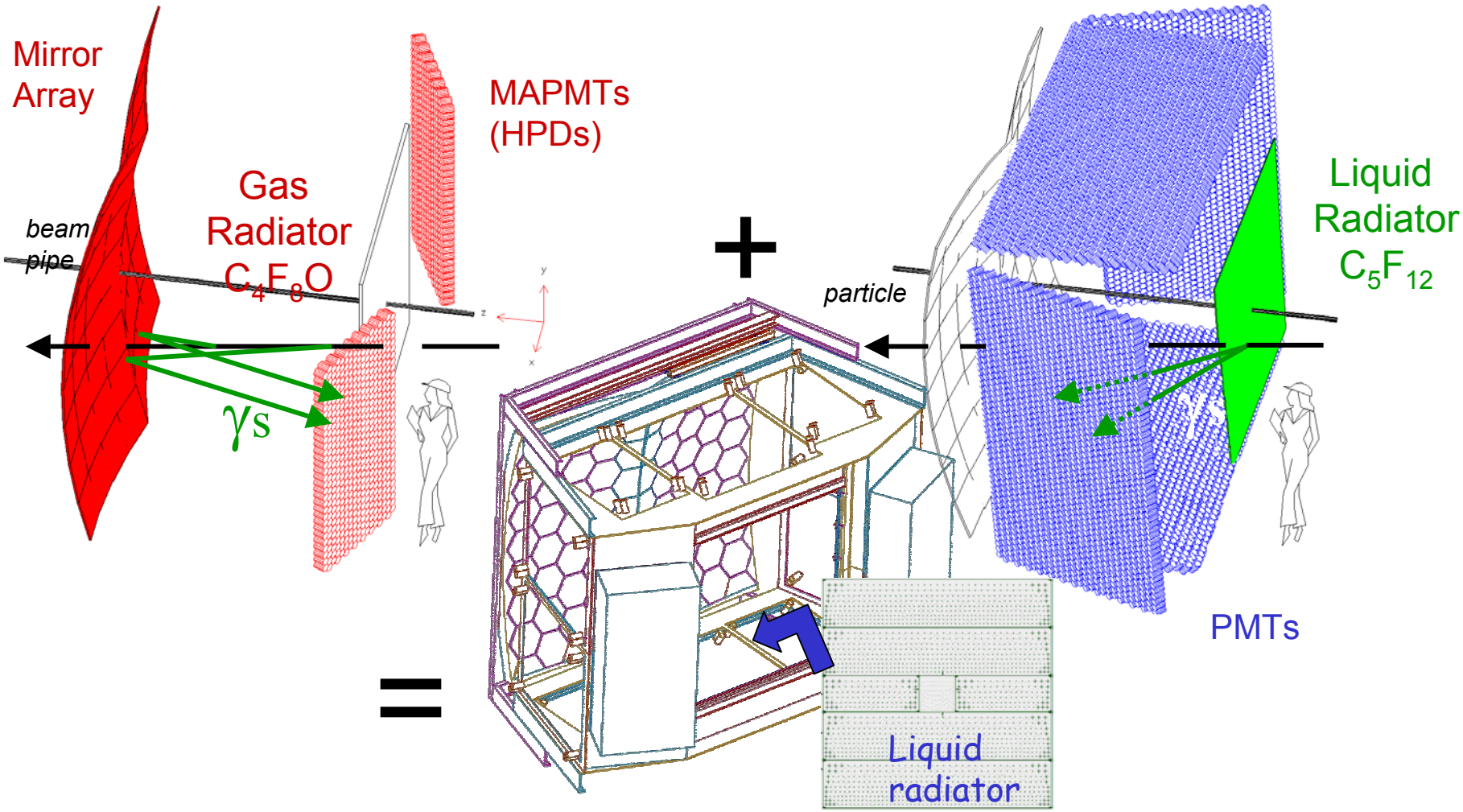
- Charged particle identification is a key element of our experiment. The Ring Imaging Cherenkov Detector (RICH) has three main goals:
  - Distinguish $\pi$,K and p over most of the momentum range relevant for hadronic decays of the $B_d$,$B_u$ and $B_s$ mesons (3-70 GeV)
  - Maximize the impact of K tagging, by identifying $\pi$,K and p down to very low momentum (~3GeV)
  - Extend the momentum and solid angle coverage where we can achieve excellent lepton ID (complementing the $\mu$ and e-cal detectors)



# The BTeV RICH Components

Mirror Focused Gas Radiator RICH

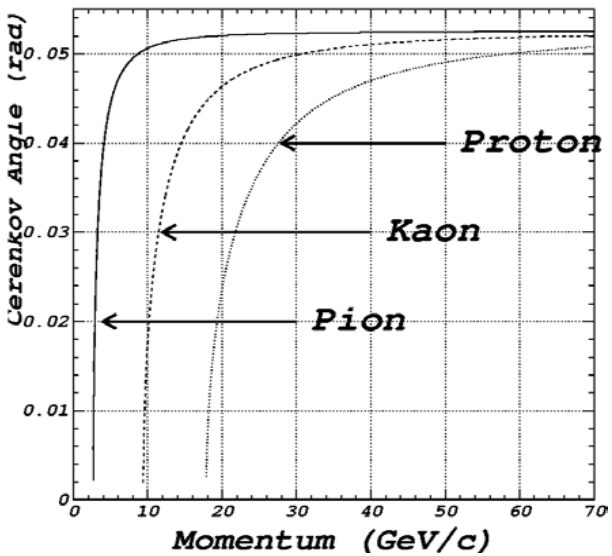
Proximity Focused Liquid RadiatorRICH



# The BTeV RICH: a good match to our physics goals

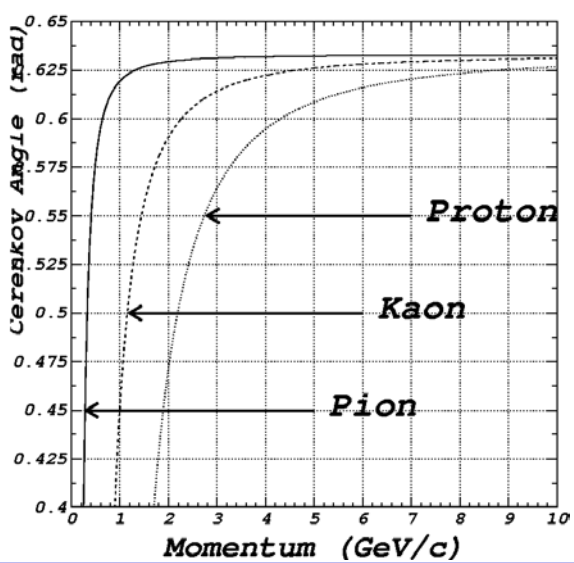
Gas

$C_4F_8O$




Liquid

$C_5F_{12}$




- 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

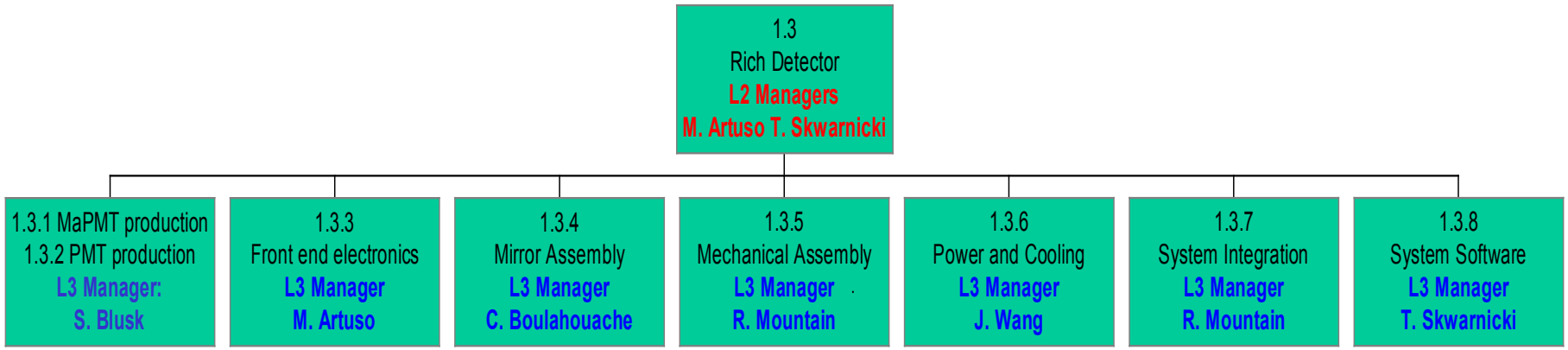
# RICH Components WBS 1.3

- Photon detectors for GAS RICH
- Photon detectors for Liquid RICH
- Front end electronics
- Mirror
- Mechanical Assembly
- High-voltage, low-voltage and cooling
- System integration and tests prior to installation in the C0 collision hall
- Software (run control, slow control and monitoring, databases)

Base cost: $12.1M (Material: $9.9M, Labor: $2.3M)

+ NSF support for R&D work

# Organization WBS 1.3



# The RICH Detector Components

- 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 RICH Photon Detector

| System | HPD | MAPMT |
|---|---|---|
| Number of tubes | 944 | 9016 |
| Cost per tube | $6353 | $529 |
| Photodetector cost | 5,997 k$ | 4,769 k$ |

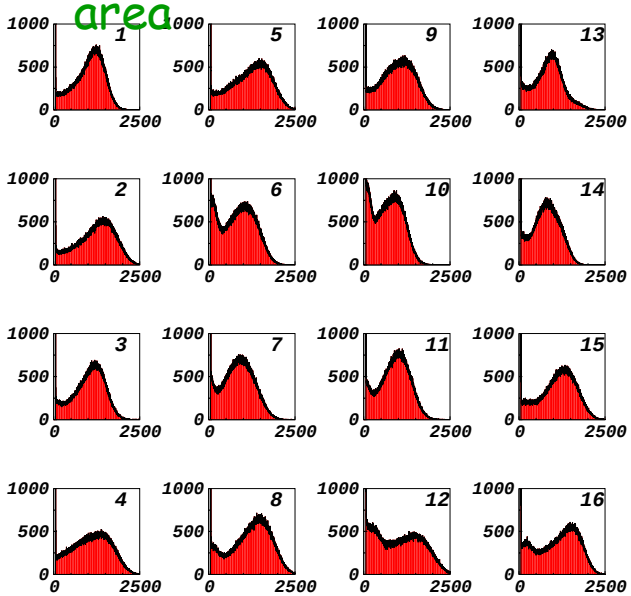
| System | HPD | MAPMT |
|---|---|---|
| Effective pixel size | 5.5 mm hex | 6 mm square |
| $N_\gamma$<br>$\sigma_{track}$ | 50.3<br>0.118 mr | 52.0<br>0.115 mr |
| HV | -20kV and<br>-19.9kV and<br>-15.8kV and<br>-0.05 kV | -0.9 kV |
| Current draw | no | yes |
| Gain | $5 \times 10^3$ | $10^6$ |
| Magnetic field sensitivity | Large, but OK shielded | R8900 – OK shielded |

- Both systems satisfy our physics requirements
- Cost and system issues favor the MAPMTs →MAPMTs are our baseline photon detector

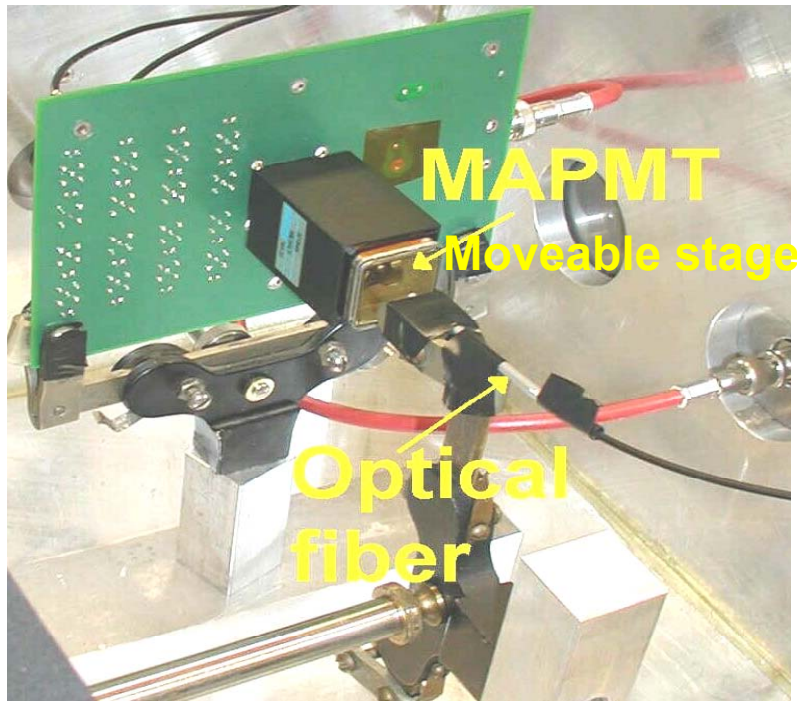
# MAPMT Performance Characterization

We have acquired 2+ 52 MAPMTs: 2 Fully characterized & 52 recently purchased for upcoming test beam studies.

- Characterization steps:
  - Plateau
  - Active area
  - Gain and collection efficiency (CE) variation over the tube area

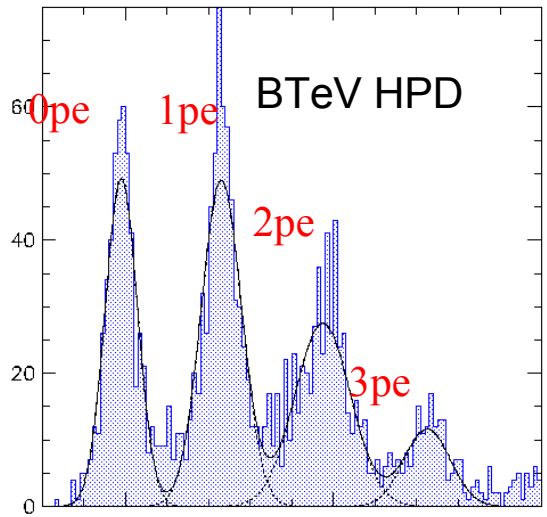


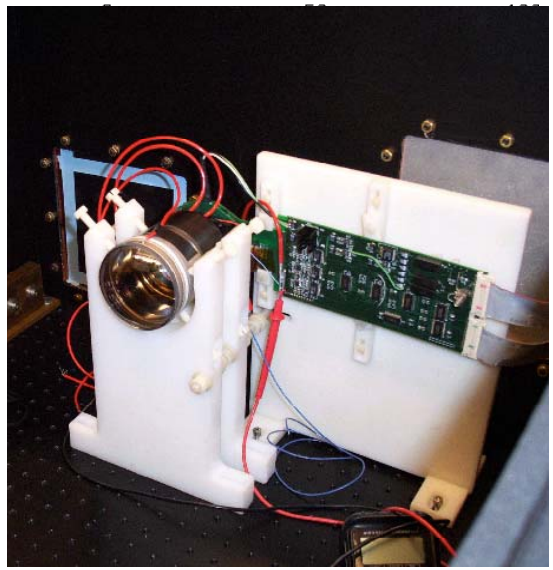

PULSE HEIGHT DISTRIBUTIONS FOR THE 16 CHANNELS OF R8900-M16 PROTOTYPE



# BTeV HPD

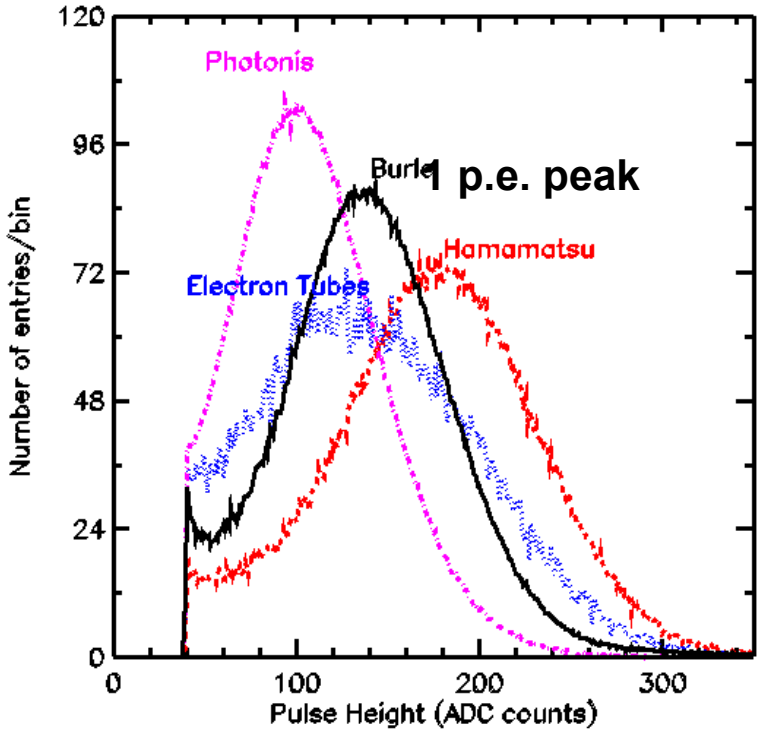
- 15 prototypes tested at Syracuse with LED light using CLEO III VA-RICH readout:
  - HPD works as expected
  - The development was a success!
- HPD being tested with VA_BTeV front end electronics
  - Seen response to single photoelectron
  - A system of 15 fully instrumented HPD's is being assembeld and will be studied in a test beam at FNAL in June 2004



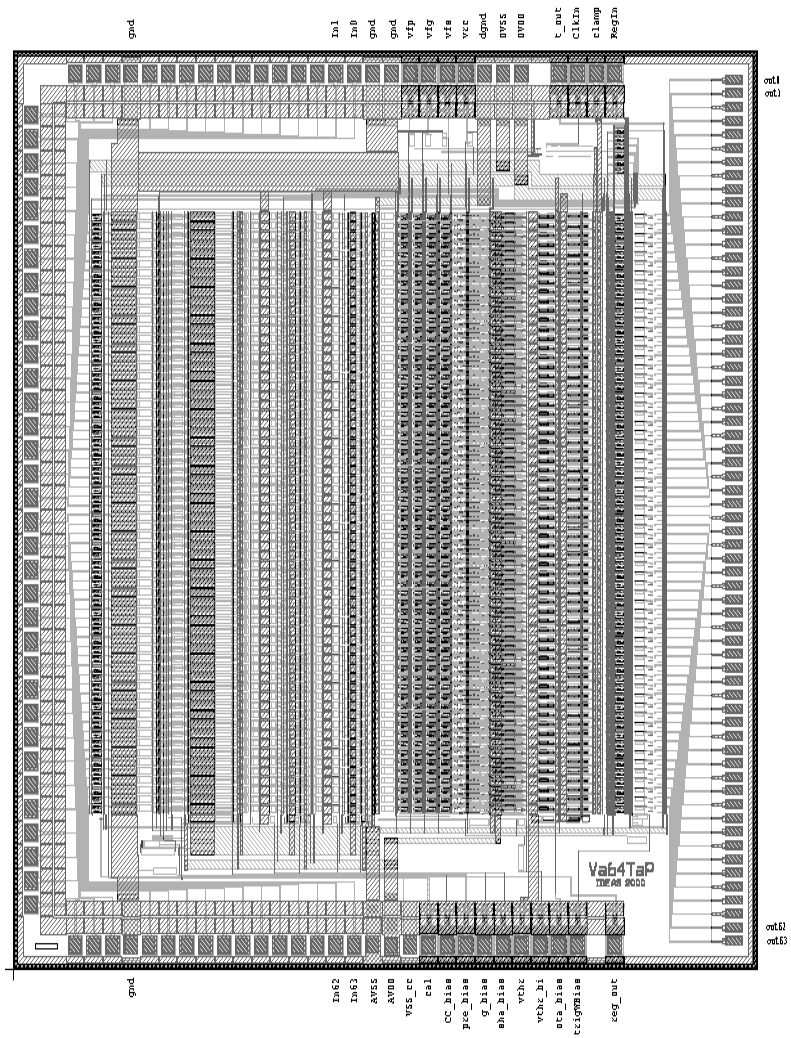



# Photodetectors for the Liquid Radiator RICH

- 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)



# Photon detector electronics

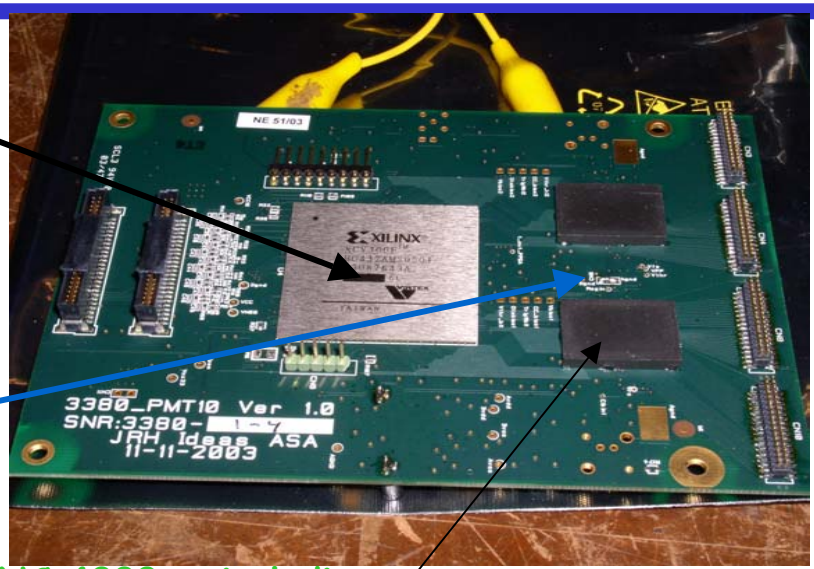



- FRONT END ASIC must
  - Low noise (~1000 $e^-$)
  - On chip sparsification
  - High Dynamic range
  - Parallel digital readout to allow event synchronization
- PROTOTYPING STEPS implemented:
  - VA_BTeV1 [ for HPD readout: low noise (500$e^-$ ENC), discriminator not optimized for high counting rates]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

# Front End hybrids

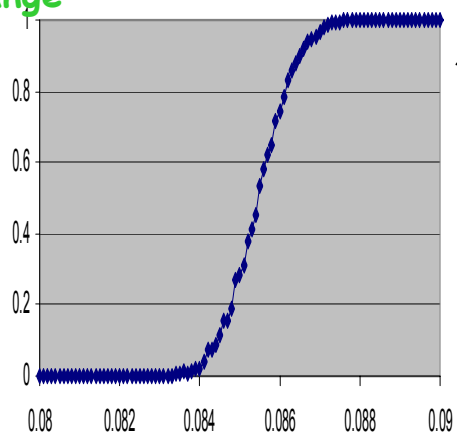
FPGA for data flow control

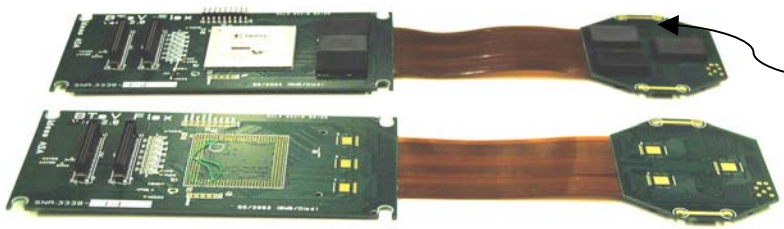
2 ASICs under light shield-caps

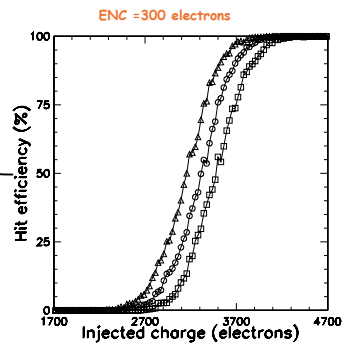



- 2 ASIC [128 channels] hybrids designed to process the information of 8 MaPMTs.
- Test bench characterization of 15 hybrids produced for the test beam shows that they match our requirements.
- Alternative solution for HPD engineered and tested.

measured ENC 4000 $e^-$ including coherent noise, high dynamic range



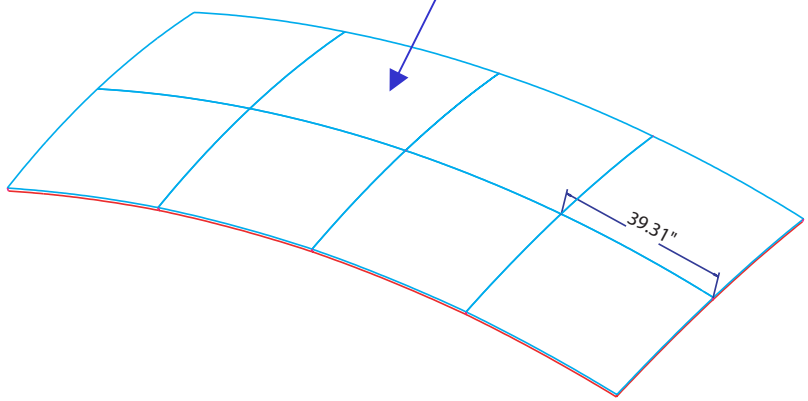





# The RICH Mirror System

- 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

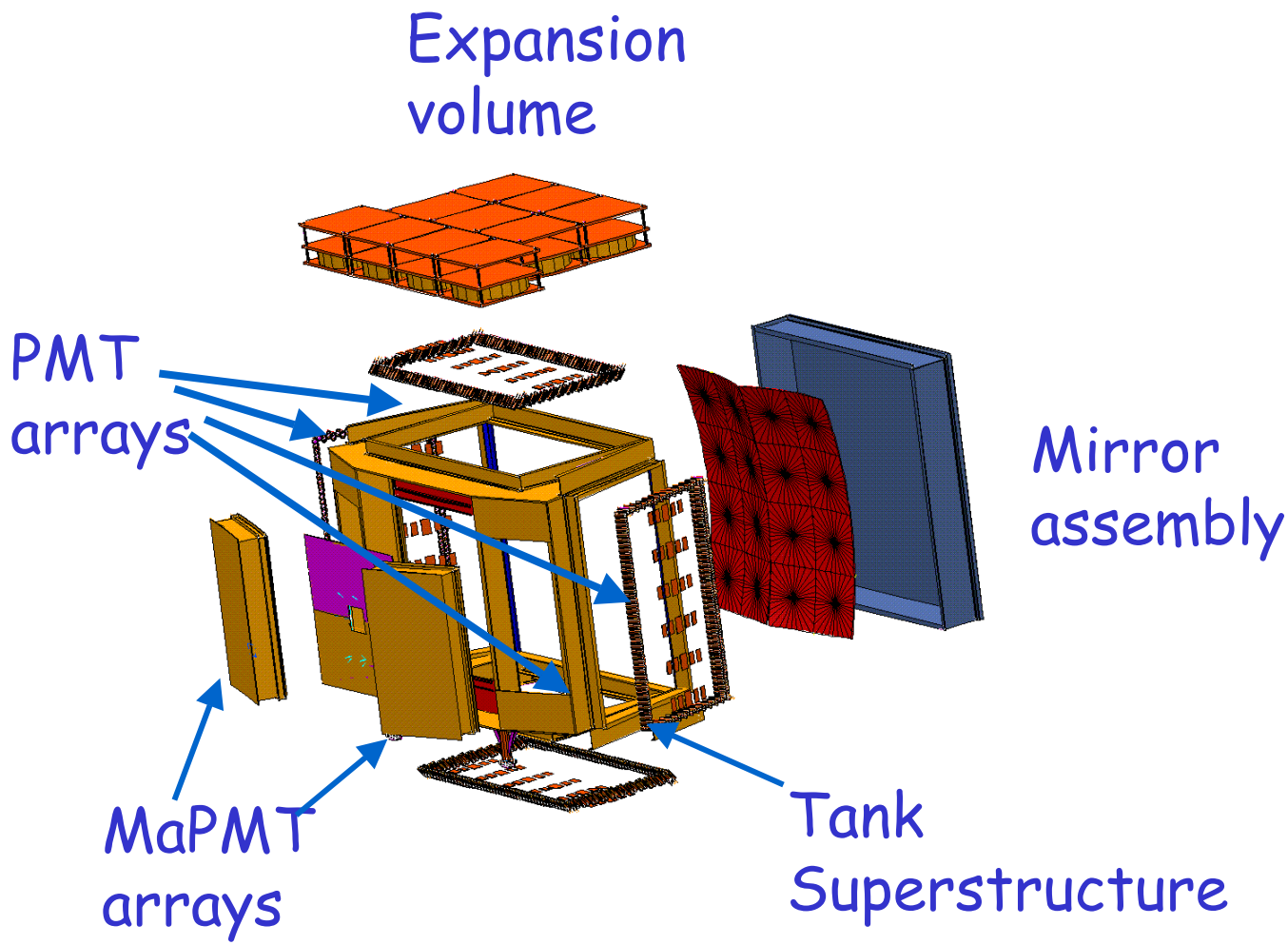
½ of RICH mirror based on CMA segment design




Example of CMA PROJECTS

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

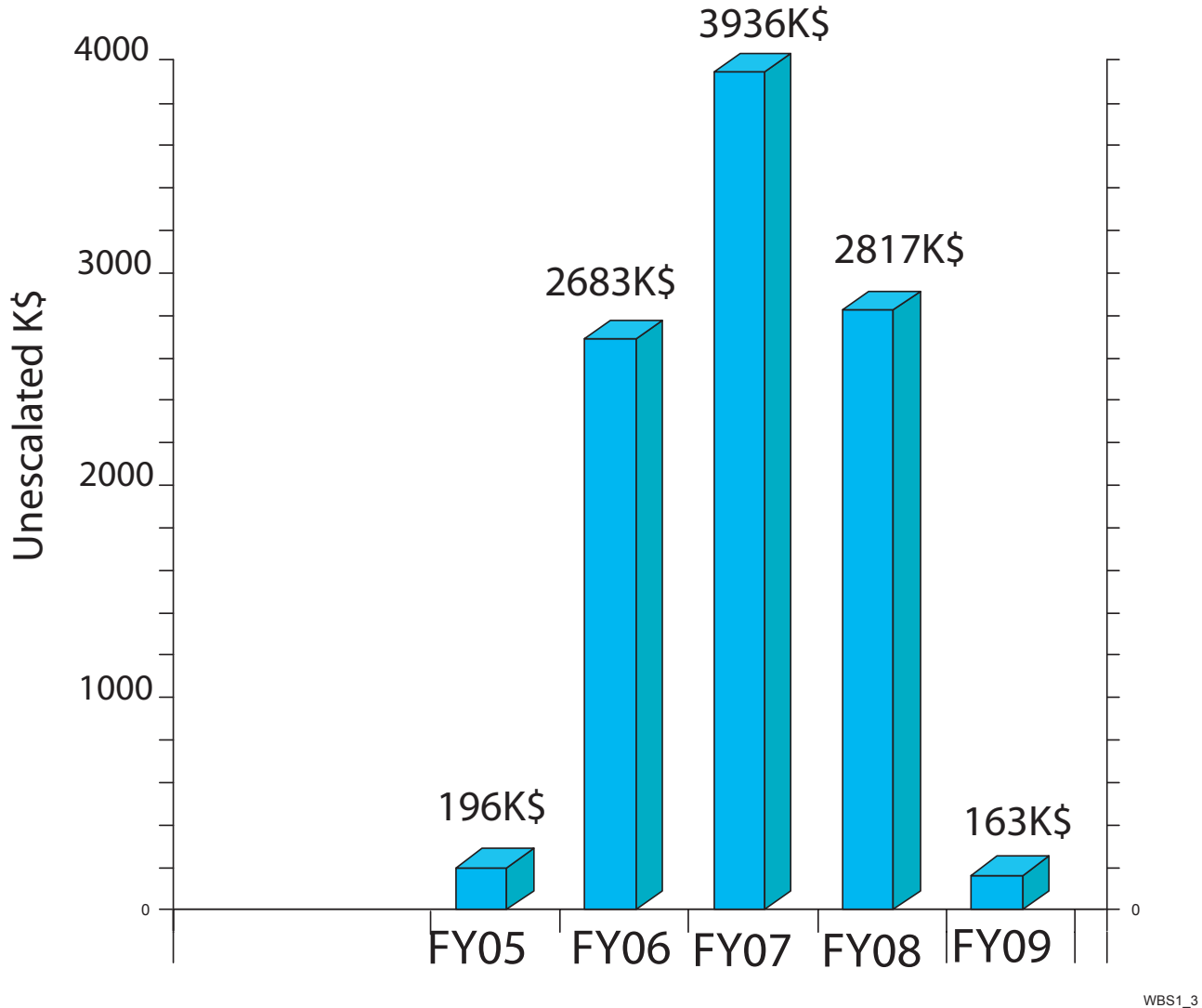
# The RICH Vessel Superstructure



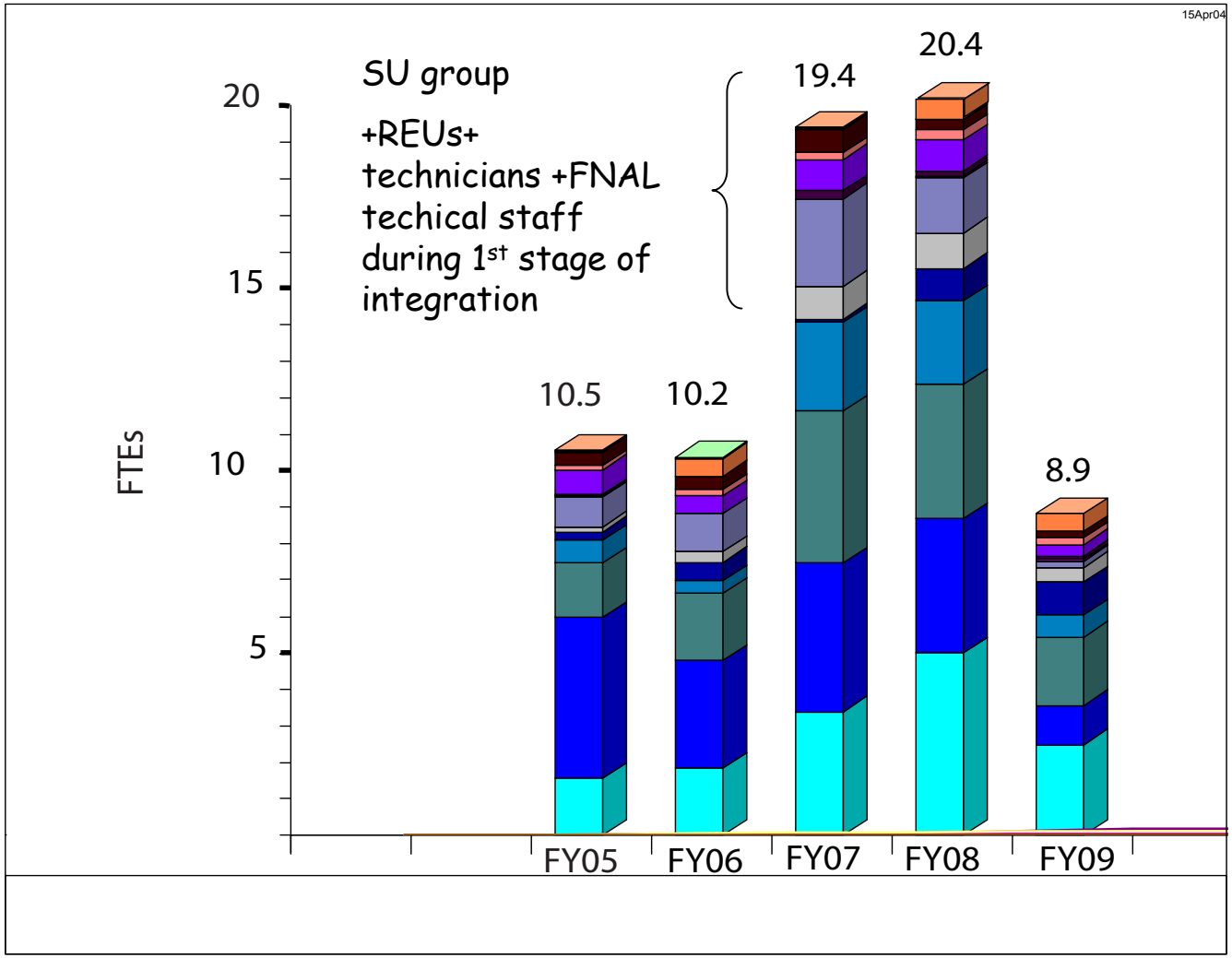
# Construction Cost WBS 1.3

| Activity ID | Activity Name | Base Cost ($) | Material Contingency (%) | Labor Contingency (%) | Total FY05 | Total FY06 | Total FY07 | Total FY08 | Total FY09 | Total FY05-09 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.3.1 | Multi-anode PMT Photon Detectors (MAPMTs) | 5,339,792 | 40 | 32 | 0 | 2,124,674 | 3,404,812 | 1,850,772 | 66,083 | 7,446,340 |
| 1.3.2 | Photomultiplier Tubes (PMTs) | 1,082,531 | 25 | 25 | 0 | 747,859 | 575,670 | 31,565 | 0 | 1,355,095 |
| 1.3.3 | Photon Detector Electronics | 1,710,105 | 47 | 43 | 151,797 | 191,278 | 1,121,270 | 1,027,554 | 19,114 | 2,511,013 |
| 1.3.4 | Mirror Arrays | 804,286 | 53 | 34 | 0 | 893,307 | 214,146 | 86,365 | 0 | 1,193,818 |
| 1.3.5 | Mech Gas Liquid & Related Systs | 1,483,679 | 28 | 28 | 216,547 | 63,293 | 987,020 | 522,916 | 112,234 | 1,902,011 |
| 1.3.6 | Power Monit Cooling & Related Systs | 784,049 | 25 | 20 | 10,545 | 0 | 60,308 | 768,837 | 132,767 | 972,457 |
| 1.3.7 | RICH Detector Install & Integ & Test | 385,966 | 21 | 29 | 159,395 | 34,604 | 69,929 | 151,761 | 78,205 | 493,895 |
| 1.3.8 | RICH Detector SW | 198,110 | 46 | 33 | 0 | 0 | 56,275 | 107,462 | 104,469 | 268,206 |
| 1.3.9 | RICH Detector Subproj Mgmt | 272,452 | 20 | 20 | 88,690 | 98,362 | 61,186 | 36,930 | 41,775 | 326,943 |
| | | | | | | | | | | |
| **1.3** | **Subproject 1.3** | **12,060,969** | **38** | **29** | **626,974** | **4,153,377** | **6,550,615** | **4,584,165** | **554,647** | **16,469,779** |

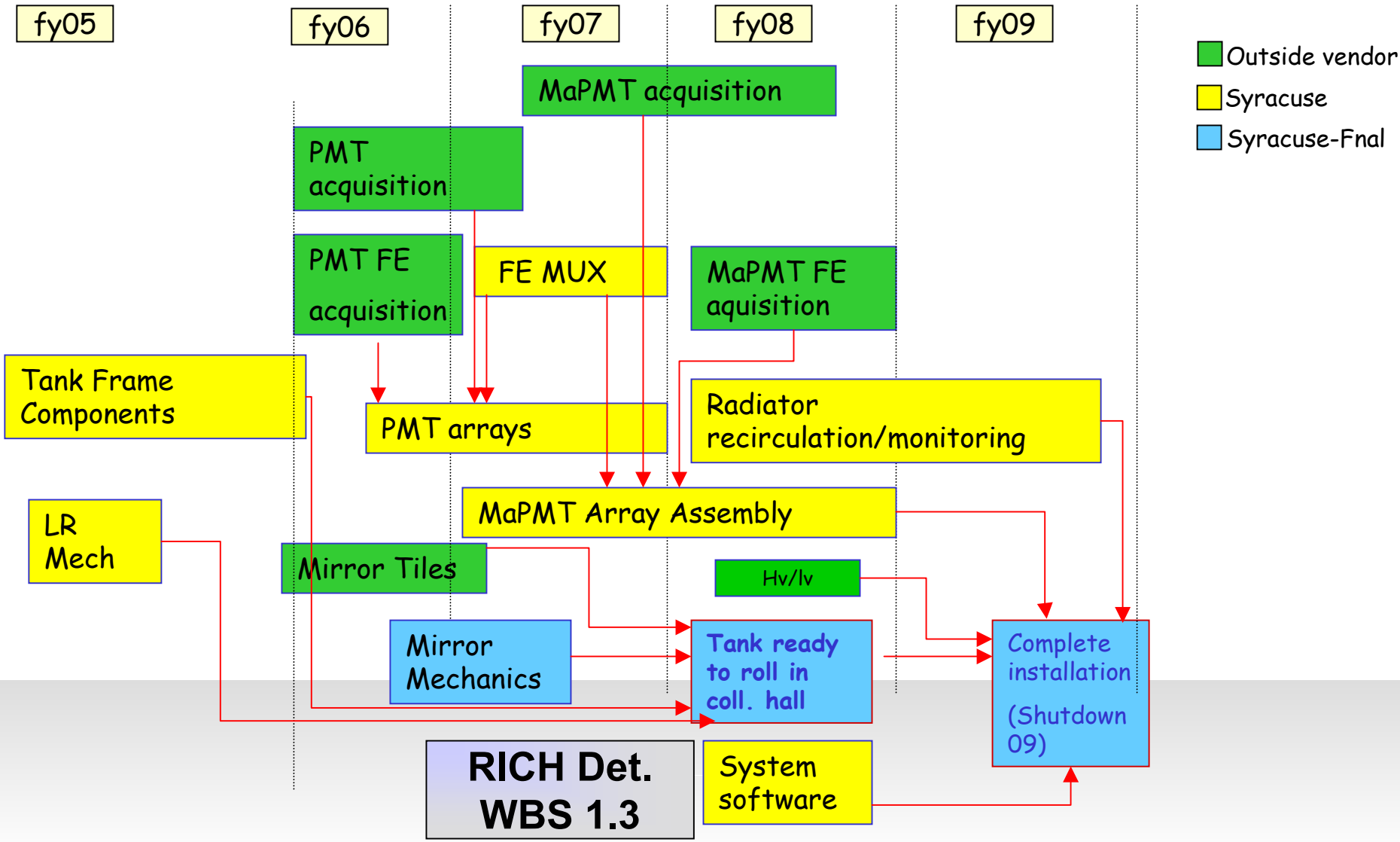
# M&S Cost Profile by Fiscal Year WBS 1.3



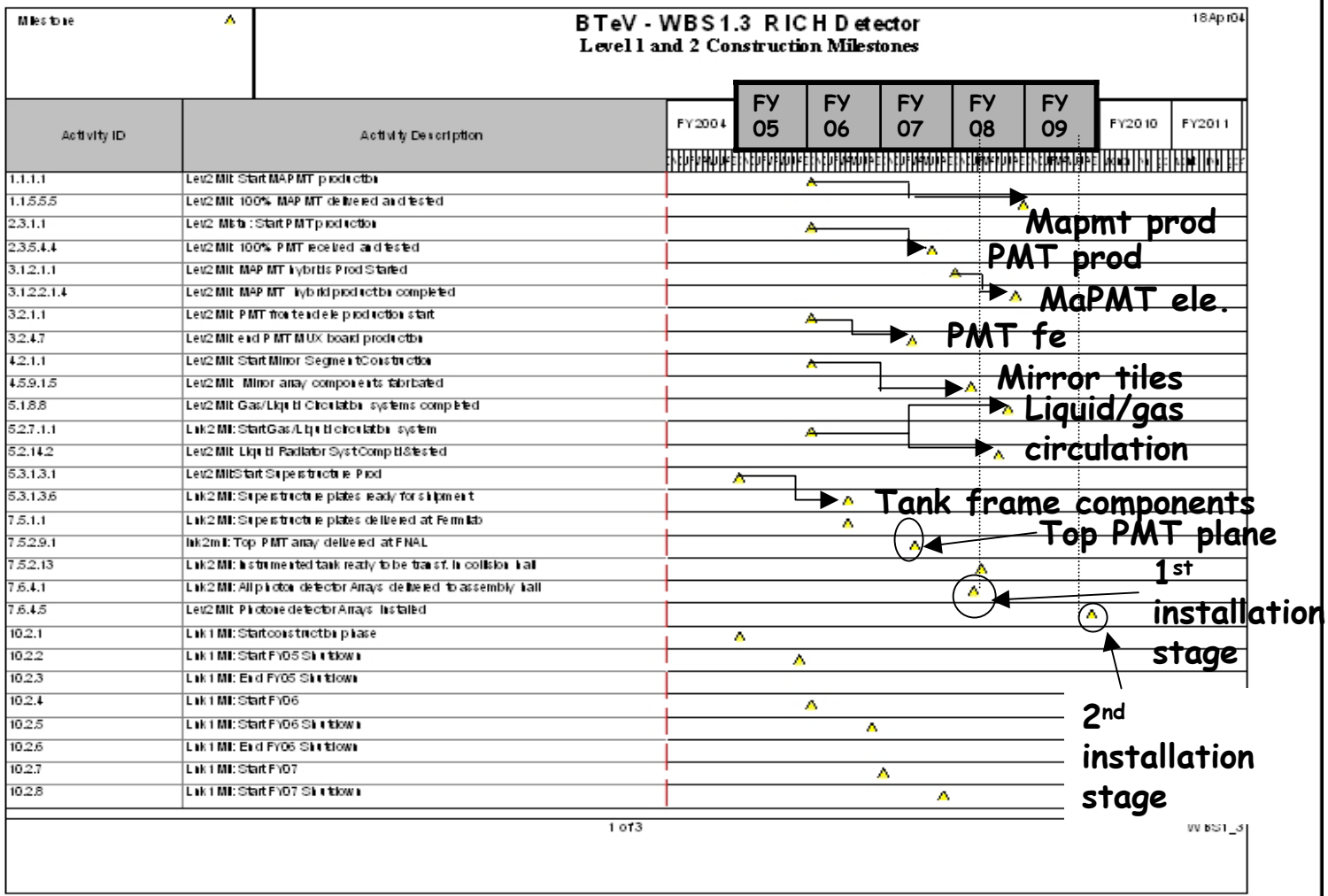
# Labor Profile by Fiscal Year WBS 1.3



# Description of project flow WBS 1.3



# Key Milestones WBS 1.3



# Critical Path Analysis WBS 1.3

**BTeV - WBS 1.3 RICH Detector**
**Barchart for Critical Path Analysis**
**Sorted by Float**

Planned
Critical
Late Dates
Milestone
Progress
Summary
Float

| Activity ID | Activity Description | Activity Type | Duration | Float | Early Start |
|---|---|---|---|---|---|
| 1.4.1 | Finalize Mount& calibration scheme Des | ASAP | 15d | 64d | 01Oct08 |
| 1.4.2 | Acq parts for Mount& calibration Syst Prod | ASAP | 60d | 64d | 22Oct08 |
| 1.4.3 | Fab parts for Mount& calibration Syst Prod | ASAP | 60d | 64d | 22Oct08 |
| 1.4.4 | Construct Mount& calibration Syst | ASAP | 40d | 64d | 23Jan09 |
| 1.4.5 | Characterize Performance of Mount& calibration Syst | ASAP | 20d | 64d | 20Mar09 |
| 3.1.2.1.1 | Lev2Mil: MAPMT hybrids Prod Started | Start Milestone | 0 | 78d | 01Oct07 |
| 3.1.2.1.2 | Visit the MAPMT electronics manufacturer (IDEAS) | ASAP | 10d | 78d | 01Oct07 |
| 3.1.2.1.3 | Write Tech Specs Doc for MAPMT hybrids | ASAP | 3d | 78d | 01Oct07 |
| 3.1.2.1.4 | Write Prod Contract Doc for MAPMT hybrid Prod | ASAP | 2d | 78d | 04Oct07 |
| 3.1.2.1.5 | Negotiate Final Contract w/MAPMT hybrid manufacturer | ASAP | 5d | 78d | 08Oct07 |
| 3.1.2.1.7 | Ship this batch of VA_BTEV hybrids & clear customs | ASAP | 10d | 78d | 12Mar08 |
| 3.1.2.2.1.1 | monitor Fab process& get ready to receive shipment | ASAP | 90d | 78d | 26Mar08 |
| 3.1.2.2.1.2 | Fab this batch of VA_BTEV hybrids | ASAP | 90d | 78d | 26Mar08 |
| 3.1.2.2.1.3 | Ship this batch of VA_BTEV hybrids & clear customs | ASAP | 5d | 78d | 01Aug08 |
| 3.1.2.2.1.4 | Lev2Mil: MAPMT hybrid production completed | Finish Milestone | 0 | 78d | 07Aug08 |
| 3.1.2.3.2.1 | Rev Vend characterization | ASAP | 1d | 78d | 08Aug08 |
| 3.1.2.3.2.2 | test hybrids | ASAP | 100d | 78d | 11Aug08 |
| 3.1.2.4.2.1 | Mount MAPMT hybrids in long term test station | ASAP | 50d | 78d | 07Jan09 |
| 3.1.2.4.2.2 | Monitor hybrids in long term test station | ASAP | 40d | 78d | 07Jan09 |
| 3.1.2.4.2.3 | test Performance upon burn-in completion | ASAP | 45d | 78d | 05Mar09 |
| 3.1.2.4.2.4 | Store batch of VA_BTEV hybrids at SU (long term) | ASAP | 2d | 78d | 07May09 |
| 3.1.2.4.2.5 | Lev2Mil: 100% MAPMT hybrids certified | Finish Milestone | 0 | 78d | 08May09 |
| 5.1.4.1.1 | Des radiator gas circulation Syst | ASAP | 80d | 16d | 27Feb08 |
| 5.1.4.1.2 | Acq Matl for gas circulation Syst | ASAP | 100d | 16d | 19Jun08 |
| 5.1.4.1.3 | Fab parts for gas circulation Syst | ASAP | 120d | 16d | 19Jun08 |
| 5.1.4.1.4 | assemble gas circulation Syst | ASAP | 60d | 16d | 10Dec08 |
| 5.1.4.1.5 | assess Performance of Proto gas circulation Syst | ASAP | 80d | 16d | 11Mar09 |
| 5.1.4.1.7 | Lev3Mil: gas circulation Syst Compld&certified | Finish Milestone | 0 | 16d | 09Jul09 |
| 5.2.2.1 | order liquid needed | ASAP | 1d | 63d | 01Oct08 |
| 5.2.2.2 | Acq liquid needed | ASAP | 60d | 63d | 02Oct08 |
| 5.2.2.3 | Lev3Mil: Received Del of radiator liquid | Finish Milestone | 0 | 63d | 30Dec08 |

Last step of calibration and monitoring infrastructure

Electronics acquisition delayed (well established component)

Gas circulation system assembled during last stages of detector integration

# Risk Analysis

- Risks
  - MaPMT acquisition: Escalation of cost due to single vendor
  - Vendor fails to deliver low mass mirrors statisfying all of our requirements within the time and budget agreed upon.
- Mitigation
  - Fully developed HPD system provides viable alternative
  - Work with multiple vendors + multiple technologies (glass, Be substrates)

# Summary

- Dual radiator RICH (mirror focused gas radiator + proximity focused liquid radiator) will provide excellent hadron identification and enhance lepton identification
- Prototypes for all the subsystems developed and studied in test stands at Syracuse and a test beam run at Fermilab is planned this Summer.
- Cost in check via multiple vendors/technologies
- Experienced team that has already built a large RICH system (CLEO RICH, operating extremely well since 1999 at CESR $e^+e^-$ collider)
- More information on the RICH Detector System (WBS 1.3) will be provided in the breakout session
  - Project Overview – Marina Artuso
  - Photon detectors – Tomasz Skwarnicki
  - Front end electronics – Marina Artuso
  - Mirror design – Tomasz Skwarnicki
  - Mechanical design and installation plans – Herman Cease

# 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]