Multianode Photo Multipliers for Ring Imaging Cherenkov Detectors

- Introduction
- Multianode Photo Multiplier Tubes
- R&D Results
  - Light Scanning Facilities
  - CERN Test Beam
- Conclusions

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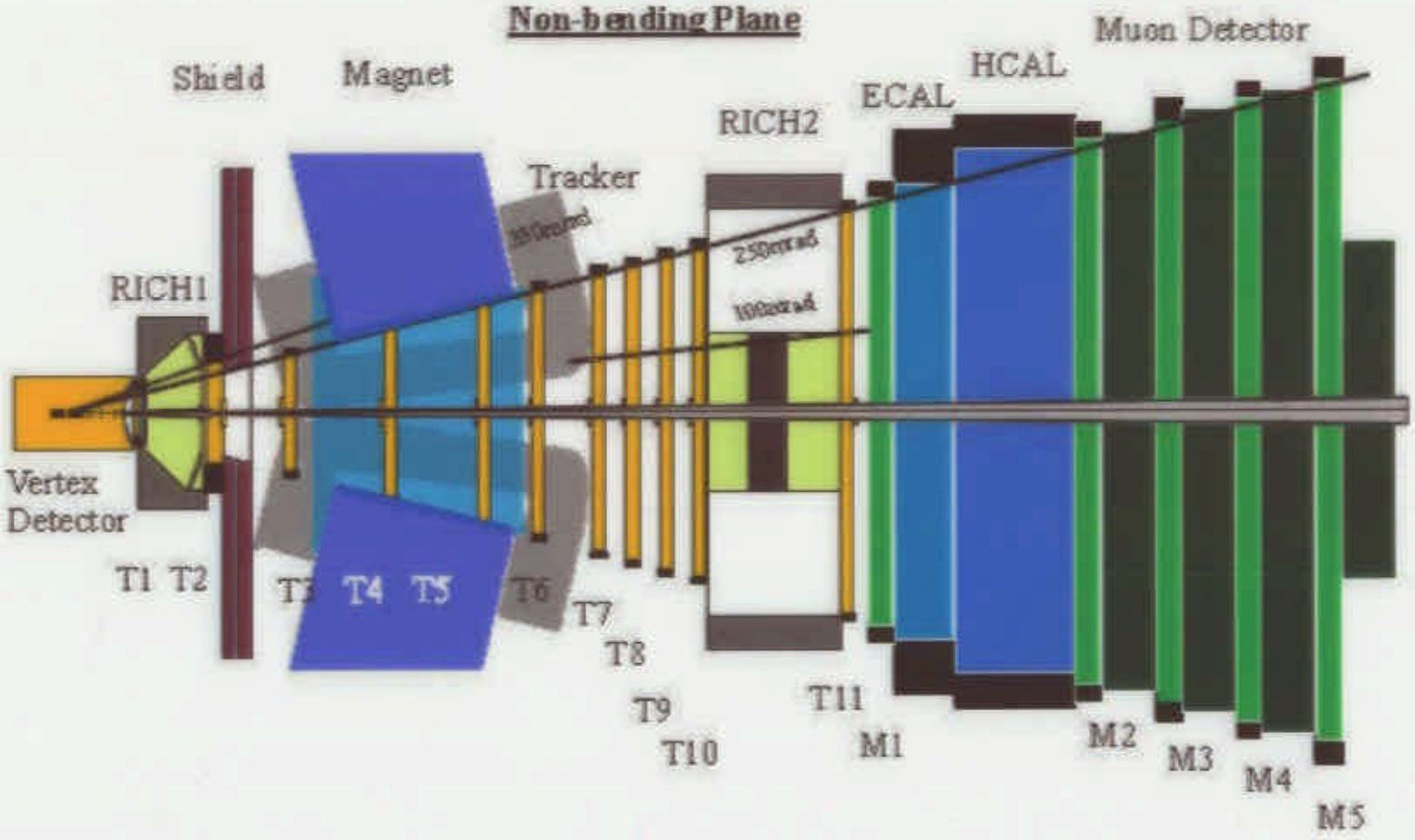
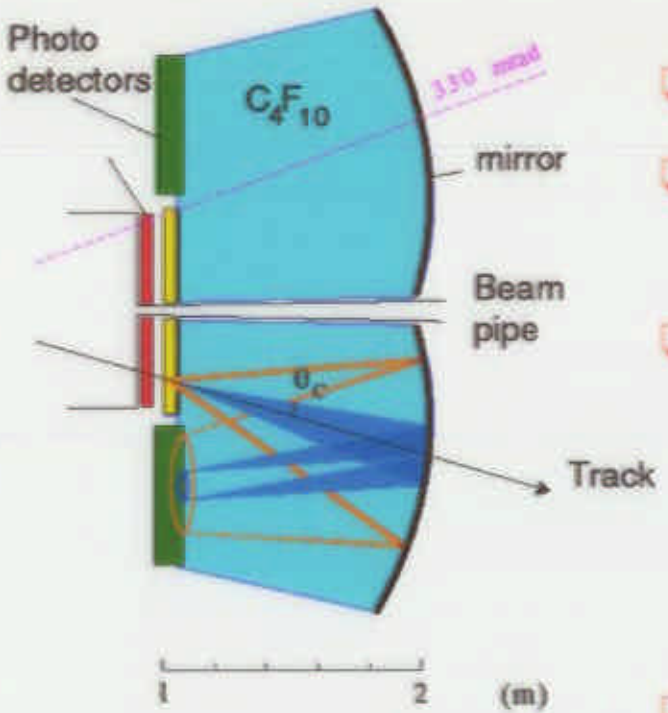
LHCb Experiment



Particle Identification in LHCb

Ring Imaging Cherenkov (RICH) Detector



- LHCb is a ~~CP~~ experiment
- Excellent particle identification required: RICH detectors
- e.g. 3 kaons in CP angle γ decay

  $B_s^0 \rightarrow D_s^- K^+$ or $D_s^+ K^-$

  ➥ $\phi\pi^-$

  ➥ K^+K^-

- Large range: $1 < p < 150$ [GeV/c]
- Challenge: Photo detectors

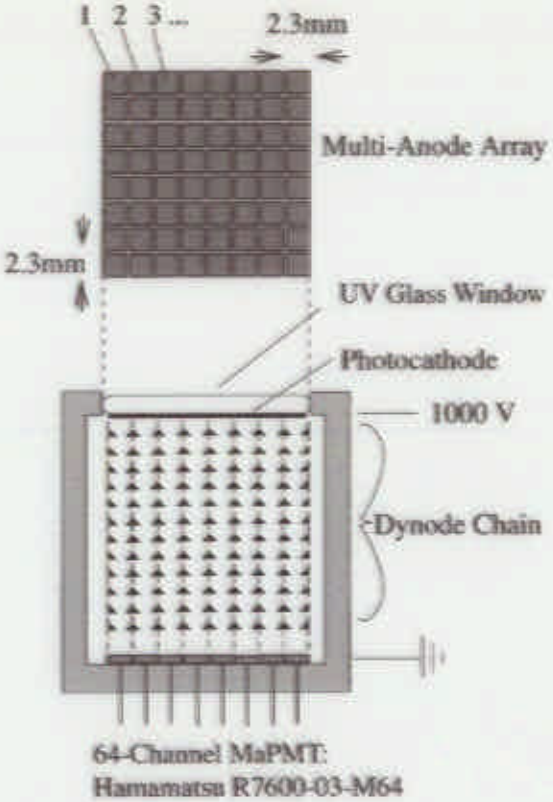
Photo Detector Requirements

- Photo detector area: 2.9 m^2
- Single photon sensitivity (200 - 600 nm) with quantum efficiency > 20%
- Good granularity: ~ 2.5 x 2.5 mm^2
- Large active area fraction: ≥ 73%
- LHC speed read-out electronics: 40 MHz
- LHCb environment: magnetic fields, charged particles

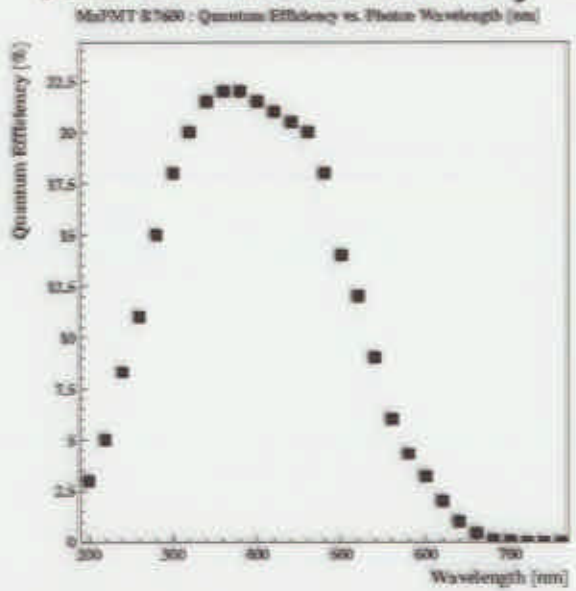
→ Options: MAPMT or HPD

Multianode Photo Multiplier Tube

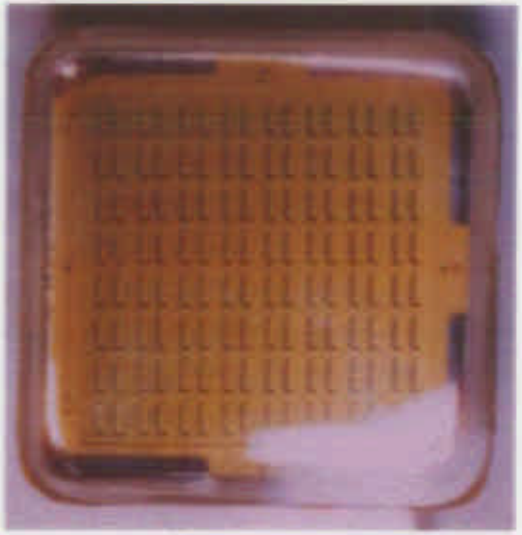
MaPMT



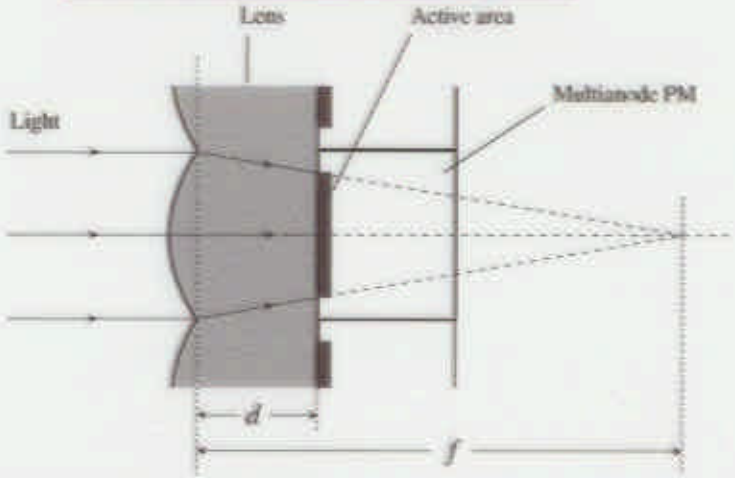
- 8x8 dynode chains
- Gain: $3 \cdot 10^5$ at 800 V
- Bialkali photo cathode,
  QE = 22% at λ = 380 nm
- UV glass window, was borosilicate,
  $\int$QE dE increased by 50 %

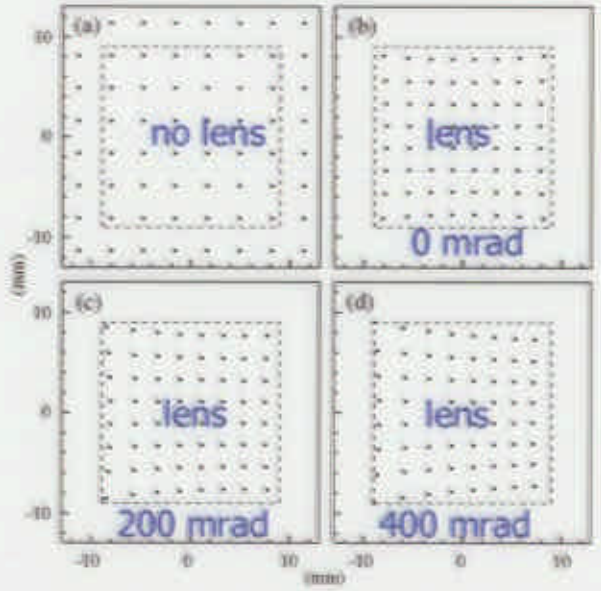


Quartz Lenses



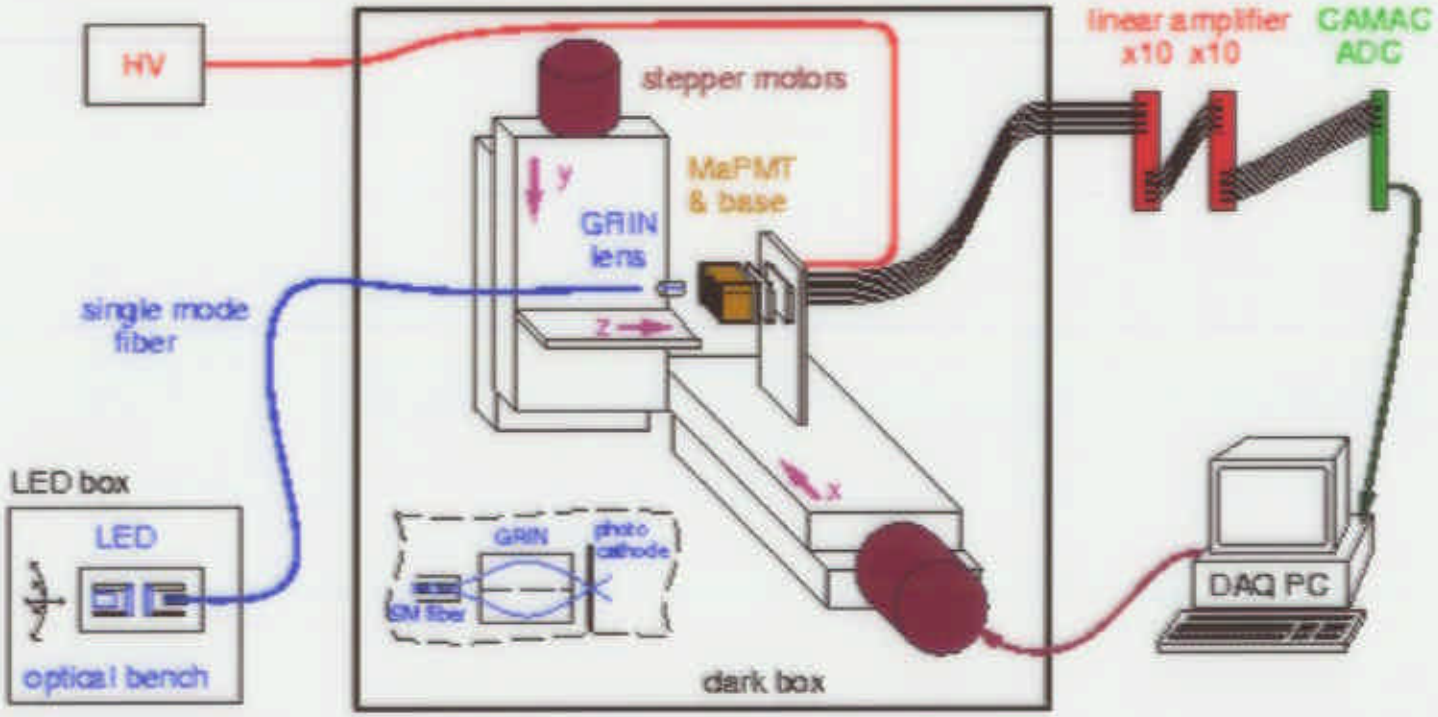
- MAPMT active area fraction: 38% (includes pixel gap)
- Increase with quartz lens with one flat and one curved surface to 85%





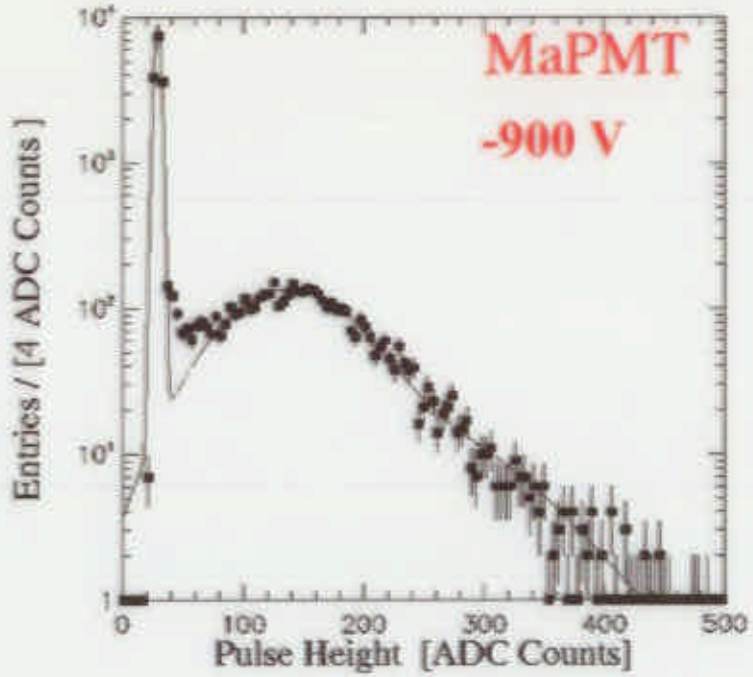
Laboratory Set-up

- XY- Scanning table
- Light source: Blue LED, single mode fibre
  gradient index lens (50 .. 100 µm spot size)



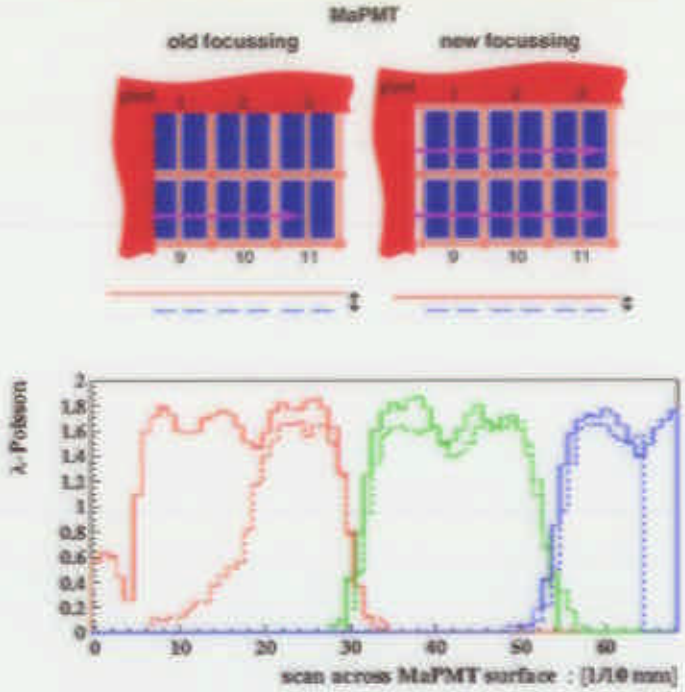
Laboratory Results

Single channel spectrum (LED)



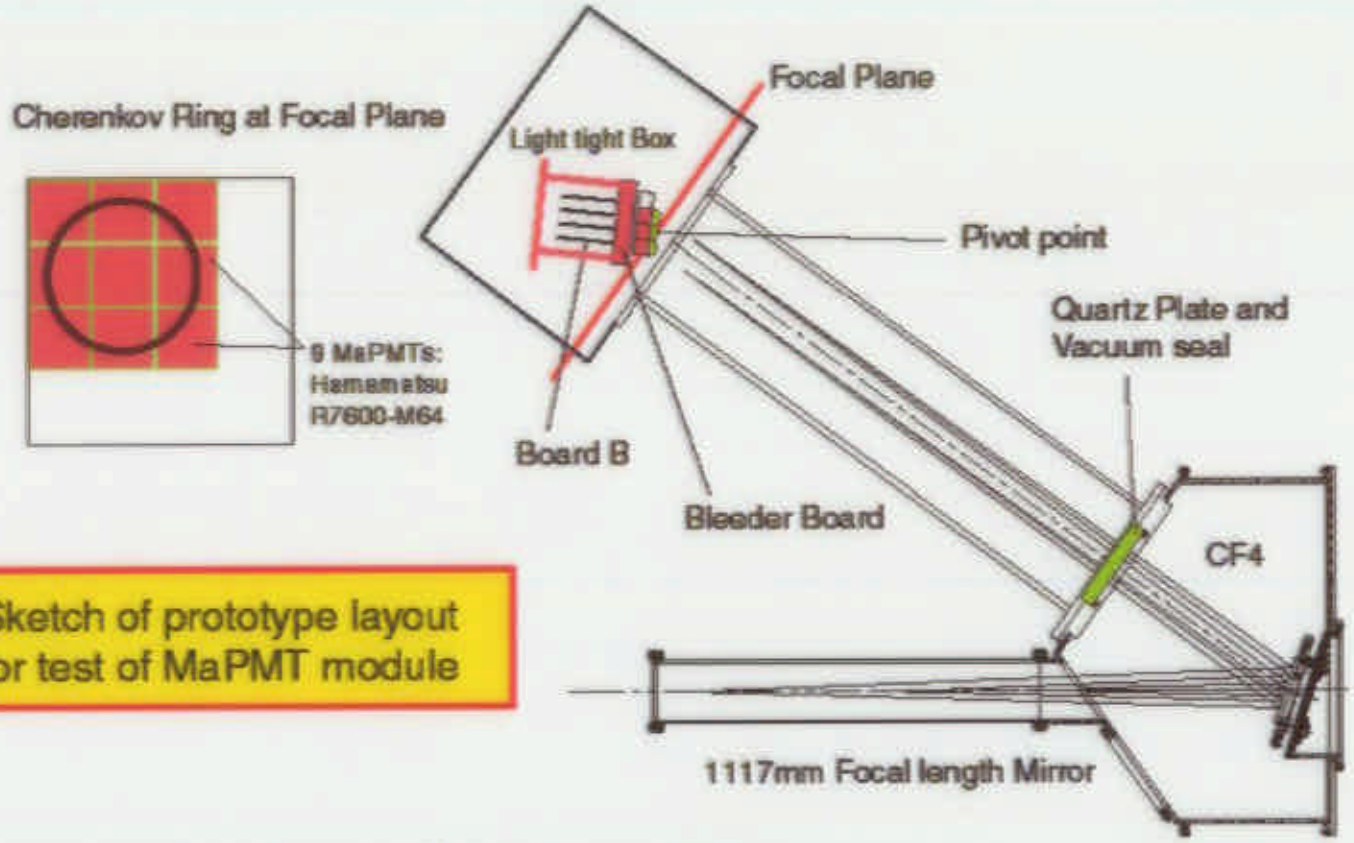
- Signal / pedestal σ = 40:1
- Signal loss below 5 σ cut: 11.5 %

Pixel scan with LED



- Better focusing improves collection efficiency

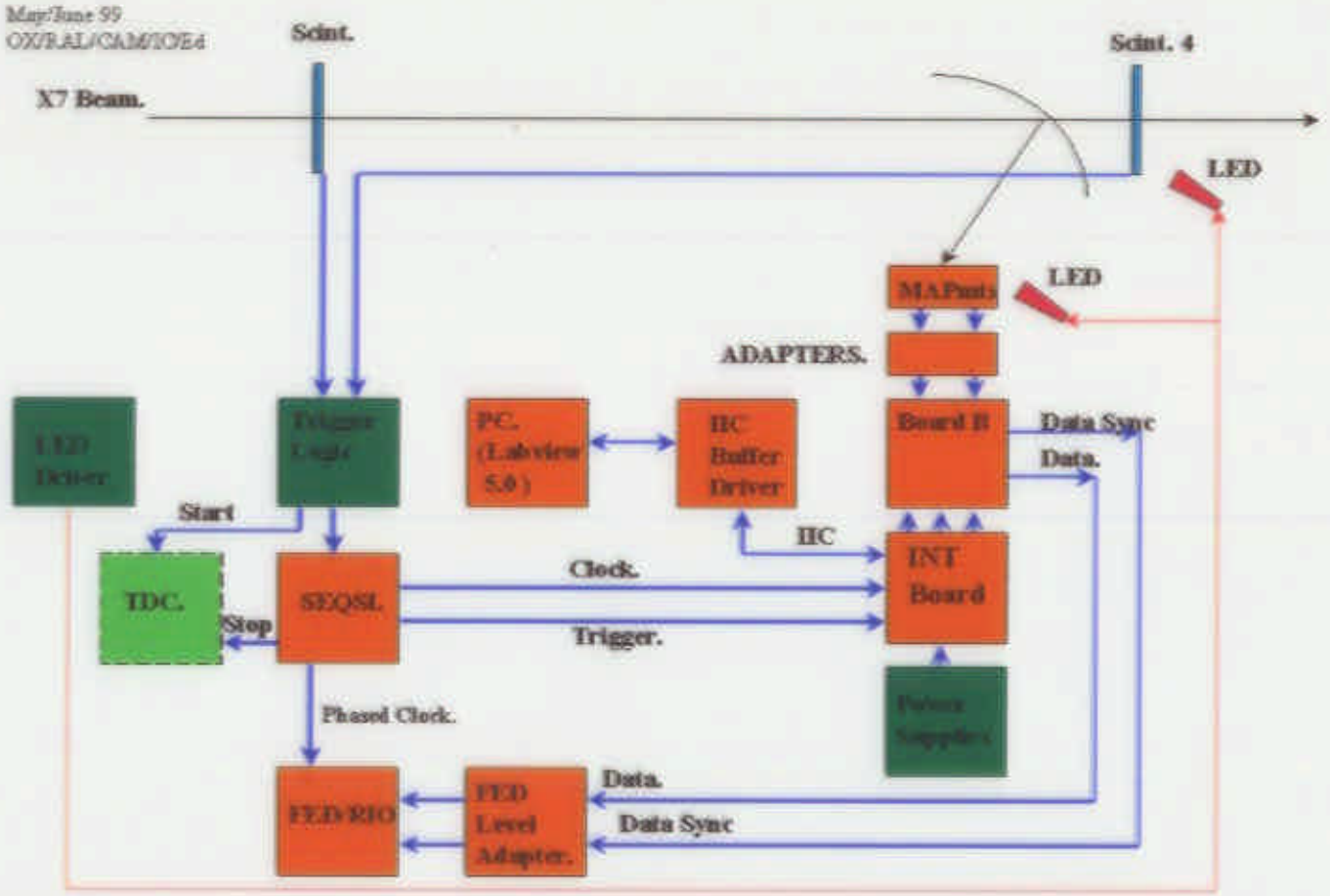
Test Beam Set-up



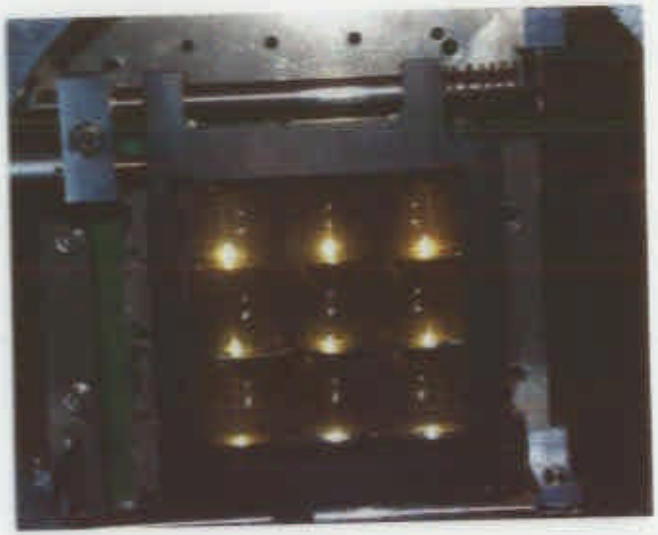
Sketch of prototype layout for test of MaPMT module

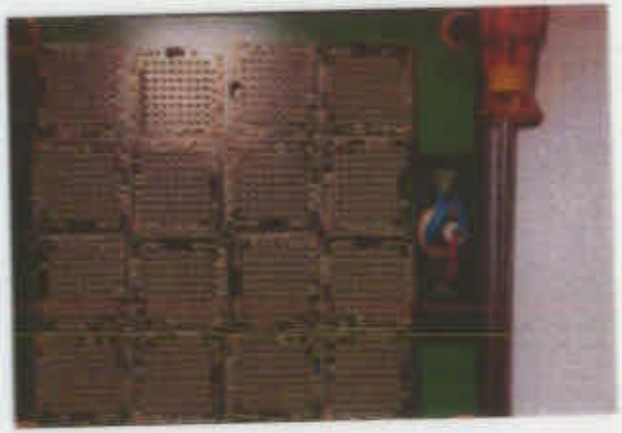
Cherenkov angle is 26 mrad with CF4 radiator at 700mbar

LHC Speed F/E Electronics

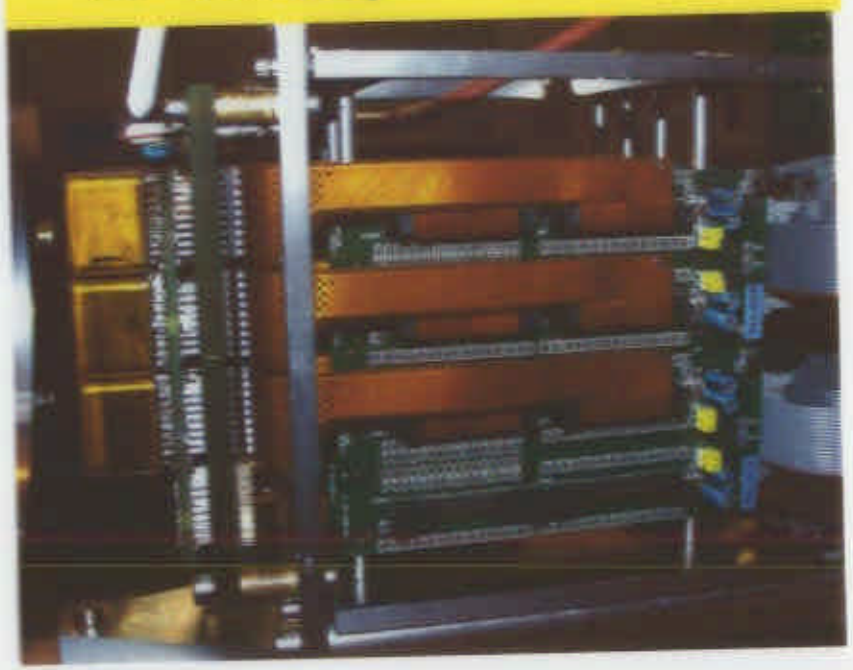


3 x 3 Cluster Set-up



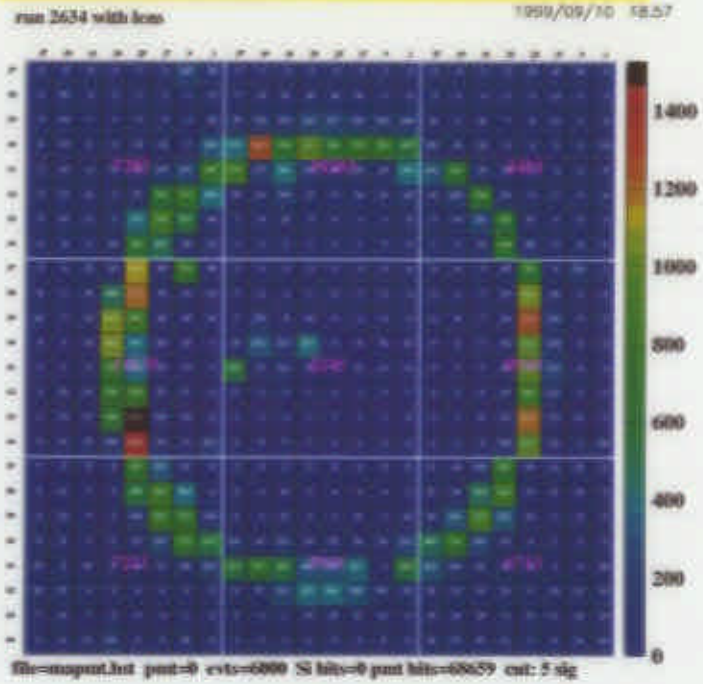


- MaPMTs, quartz lenses
- Bleeder board
- 40 MHz Read-out: APVm chip



Test Beam Results

With quartz lenses



- 6000 events
- HV: -1000 V

- Signal > 5 σ threshold, common-mode subtracted
- Cherenkov ring visible lots of photo electrons
- Some cross-talk
  - generated in electronics: APVm, ceramic Fan-in

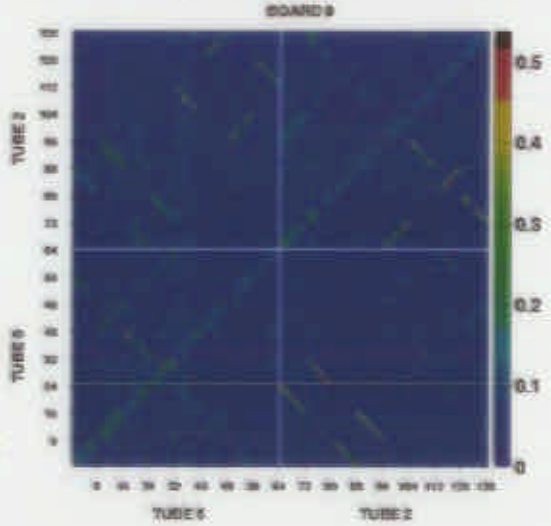
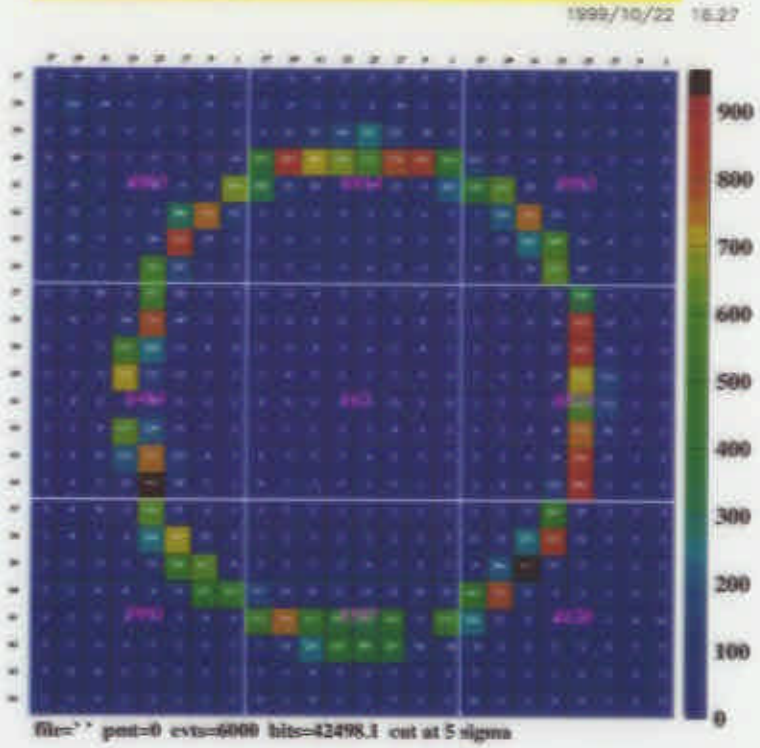


Photo Electron Yields

With quartz lenses



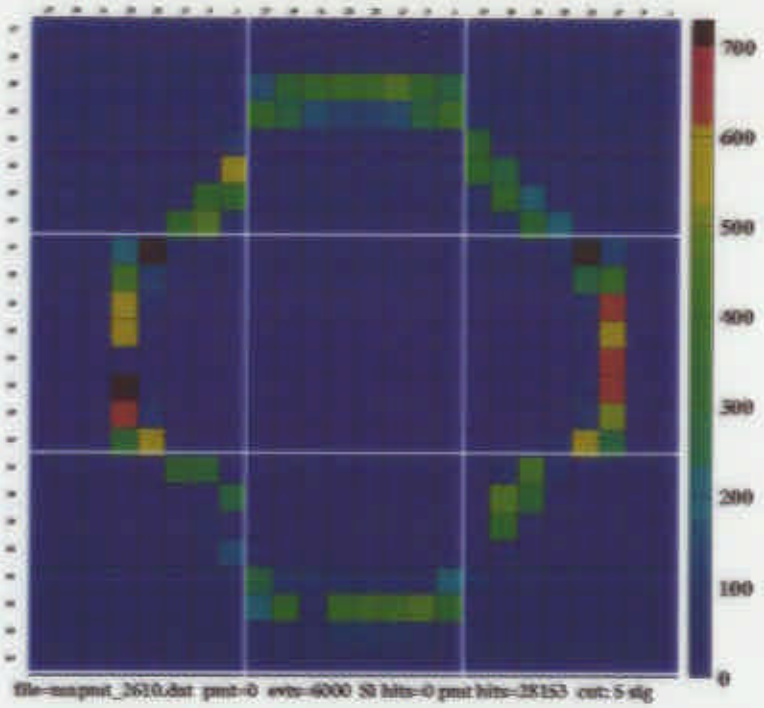
- Signal > 5 σ threshold

- Yield of p.e. corrected for
  - common-mode,
  - cross-talk,
  - a few dead pixels,
  - background 0.26 p.e.
- Observe in data
  6.51 ± 0.34 p.e.
- Expect from simulation
  6.21 p.e.
- Yield of different tubes

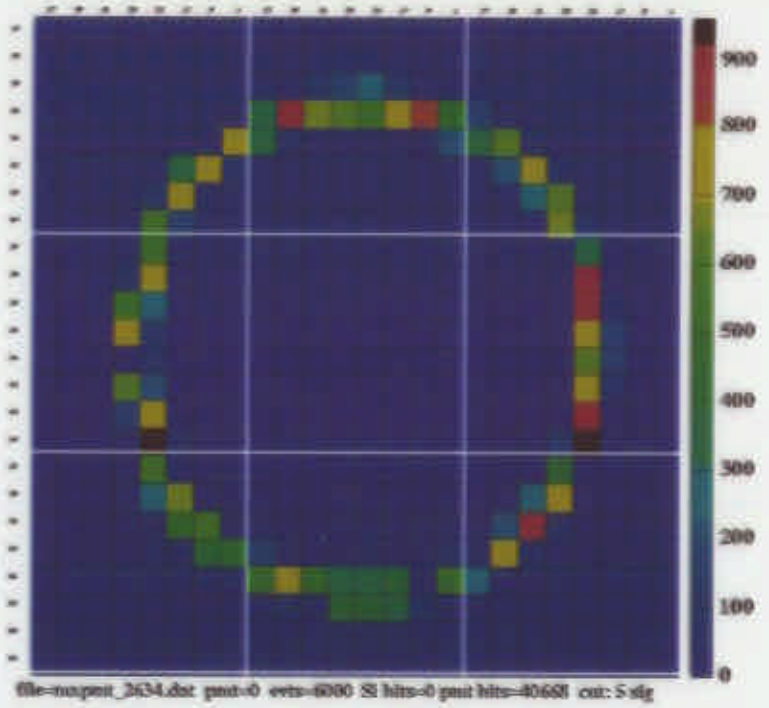
0.59	1.09	0.66
1.00	0.00	1.13
0.60	0.83	0.61

Photon Yields

No lenses



Quartz lenses

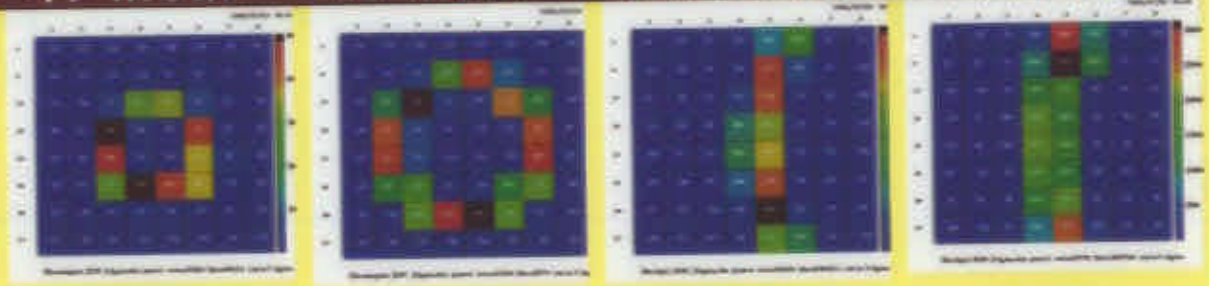


- Demonstrates lens effect
  yield ratio with/without lenses = 1.45

Single MAPMT Test Beam

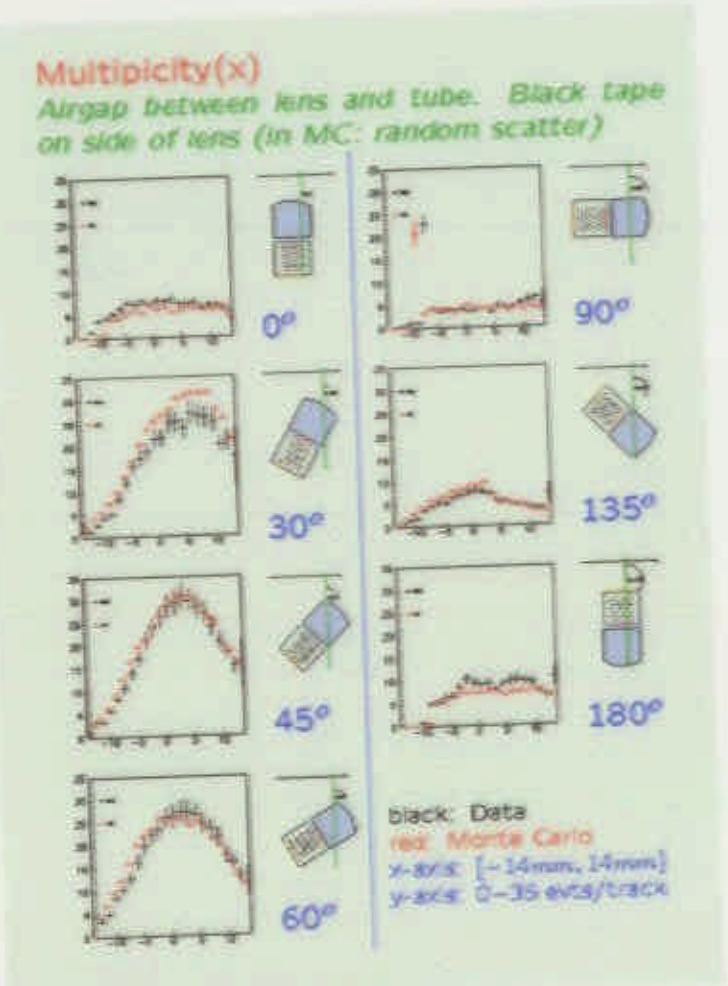
Photo electron yield

- CAMAC electronics
- RICH 1 prototype

Air radiator	*Run 2059*	*Run 2057*	*Run 2042*	*Run 2039*
Lens	*Yes*	*No*	*Yes*	*No*
Pressure	*49 mbar*	*49 mbar*	*960 mbar*	*960 mbar*
Number of detected photo electrons				
Data	0.30	0.32	1.14	0.93
Simulation	0.29	0.32	1.16	0.89

Good agreement

Charged Particles



- Charged particles traversing the lens & MAPMT produce background hits
  - Multiplicity from charged particles
    - $\in$ [5..10] for for most angles
    - up to 30 for angles around 45°

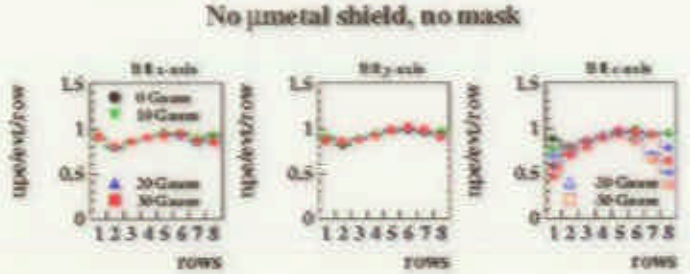
→ small background

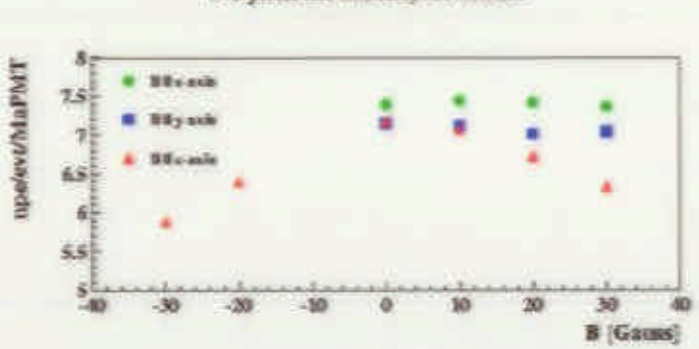
Magnetic Field Tests

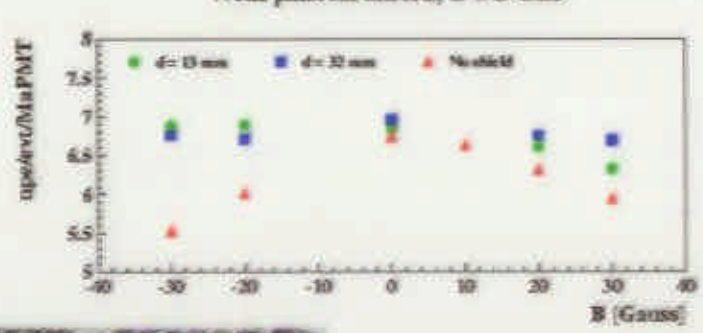
- LED
- Pin hole mask
- μ-metal shield (0.9mm)

- MAPMT tested with Helmholtz coil
- B = 0, 10, 20, 30 Gauss

Magnetic Field Results







- B Transverse
  - MAPMTs are insensitive up to mag. fields of 30 G
  - Expect mainly $B_y \leq 30$ G
- B longitudinal
  - Sensitive to $B_z \geq 10$ G gain loss, edge rows
  - Expect $B_z < 10$ G
- μ-metal:
  - Extension d = 10,13, 32 mm
  - Reduces loss no structure (d = 32 mm)

Conclusions

- Successful test of 3x3 array of MaPMTs
  - Quartz lenses and close packing work
  - Measured photon yield as expected
  - Demonstrated 40 MHz read-out
  - MaPMT works in LHCb environment
- MaPMT fulfills LHCb RICH requirements

  → MaPMT selected as LHCb backup photo detector due to high cost