Behaviour of MaPMTs in Magnetic fields

What are MaPMTs ?

- Compact Multi anode Photomultipliers Tubes

- Convert light into electric signal with spatial resolution

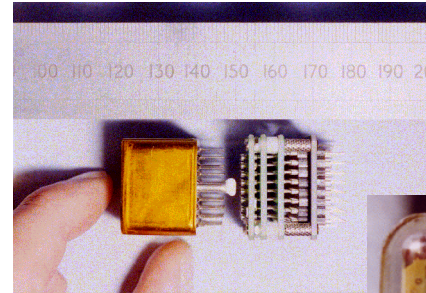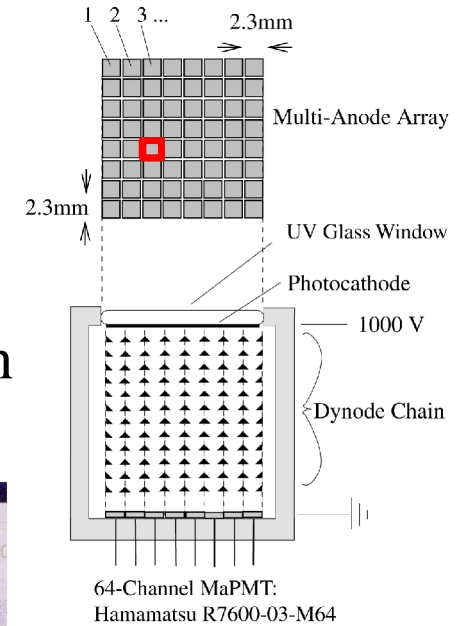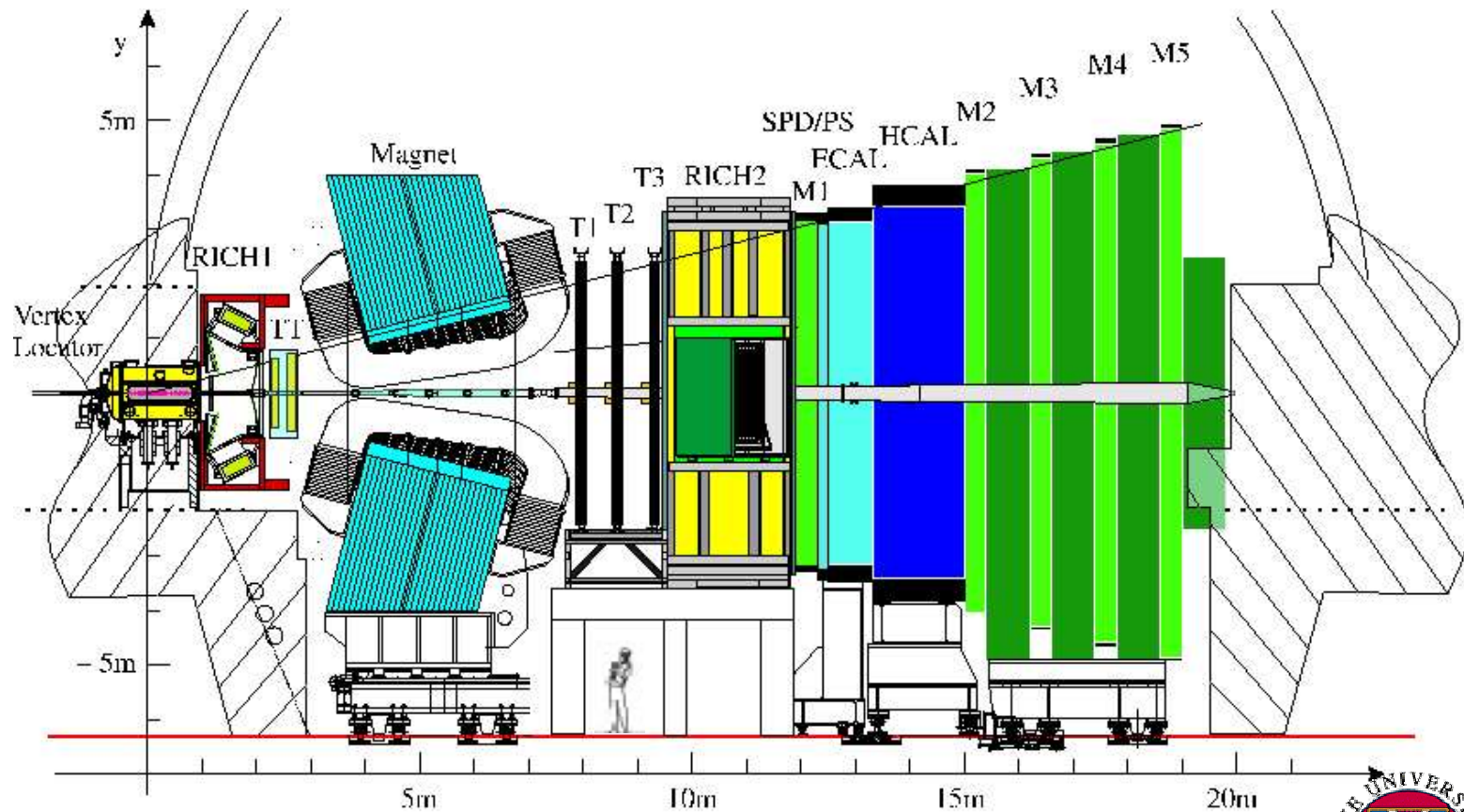 - commercial product from Hamamatsu
  - highest possible segmentation
  - 8x8 segmented anode & 12 dynode chain
  - pixel size: 2x2 mm²
  - Gain: $3*10^5$ at 800 V
  - UV glass window
  - Bialkali photo cathode
  - Quantum Efficiency (QE) = 22.5% at λ = 380 nm

MaPMT R7600 : Quantum Efficiency vs. Photon Wavelength [nm]
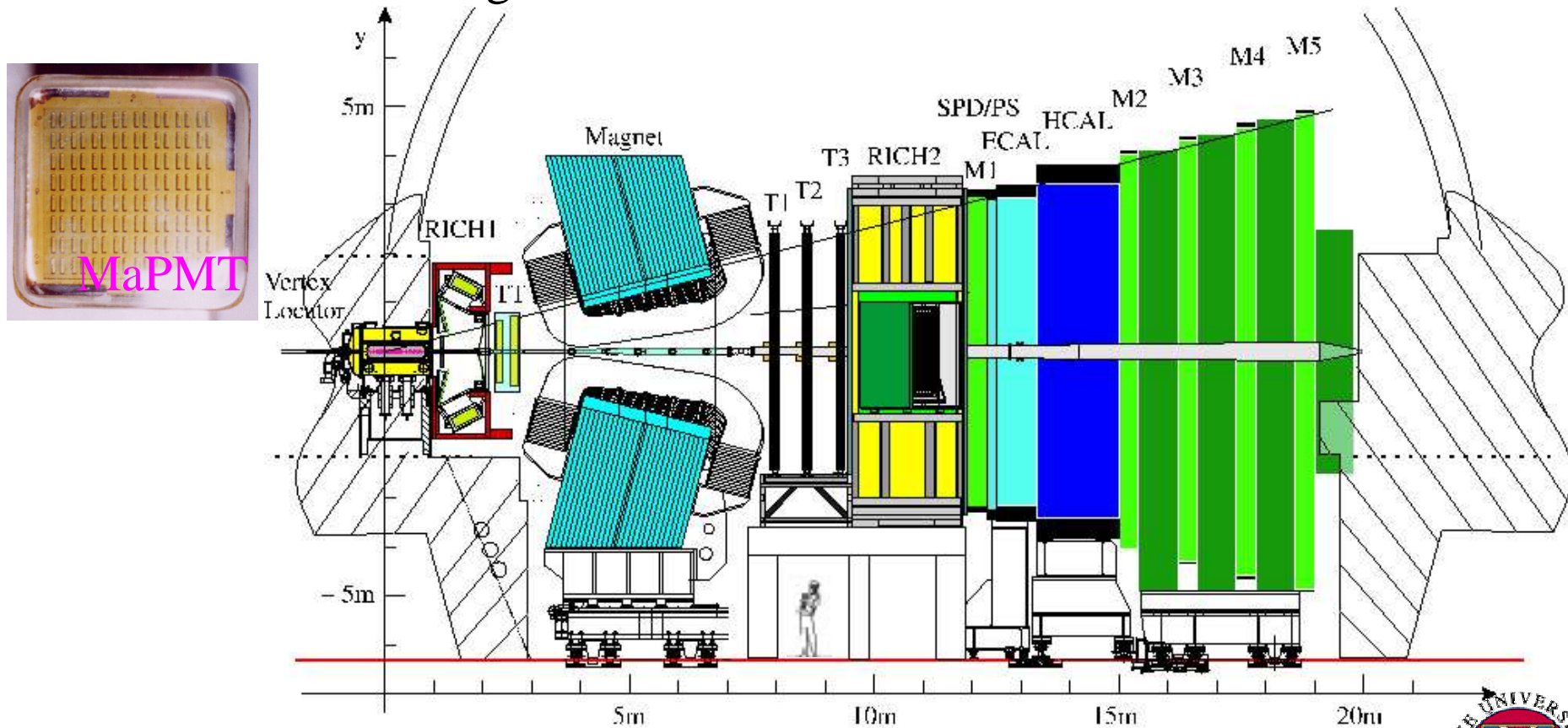
QE

Wavelength
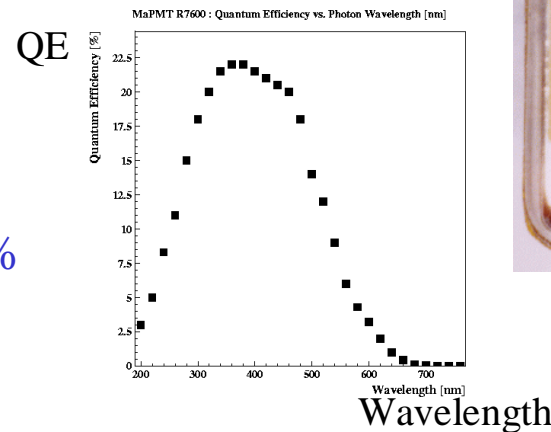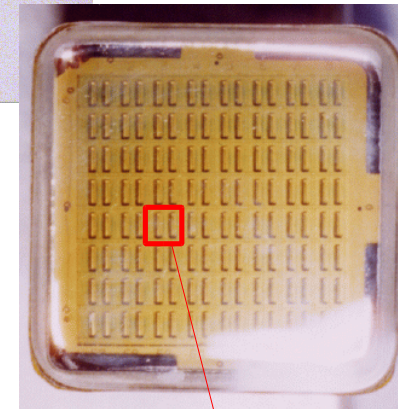
Pixel

MaPMTs and LHCb

- LHCb: Large Hadron Collider beauty experiment

- Detector being build at CERN for the study of CP violation

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- 2 Photo detectors designs

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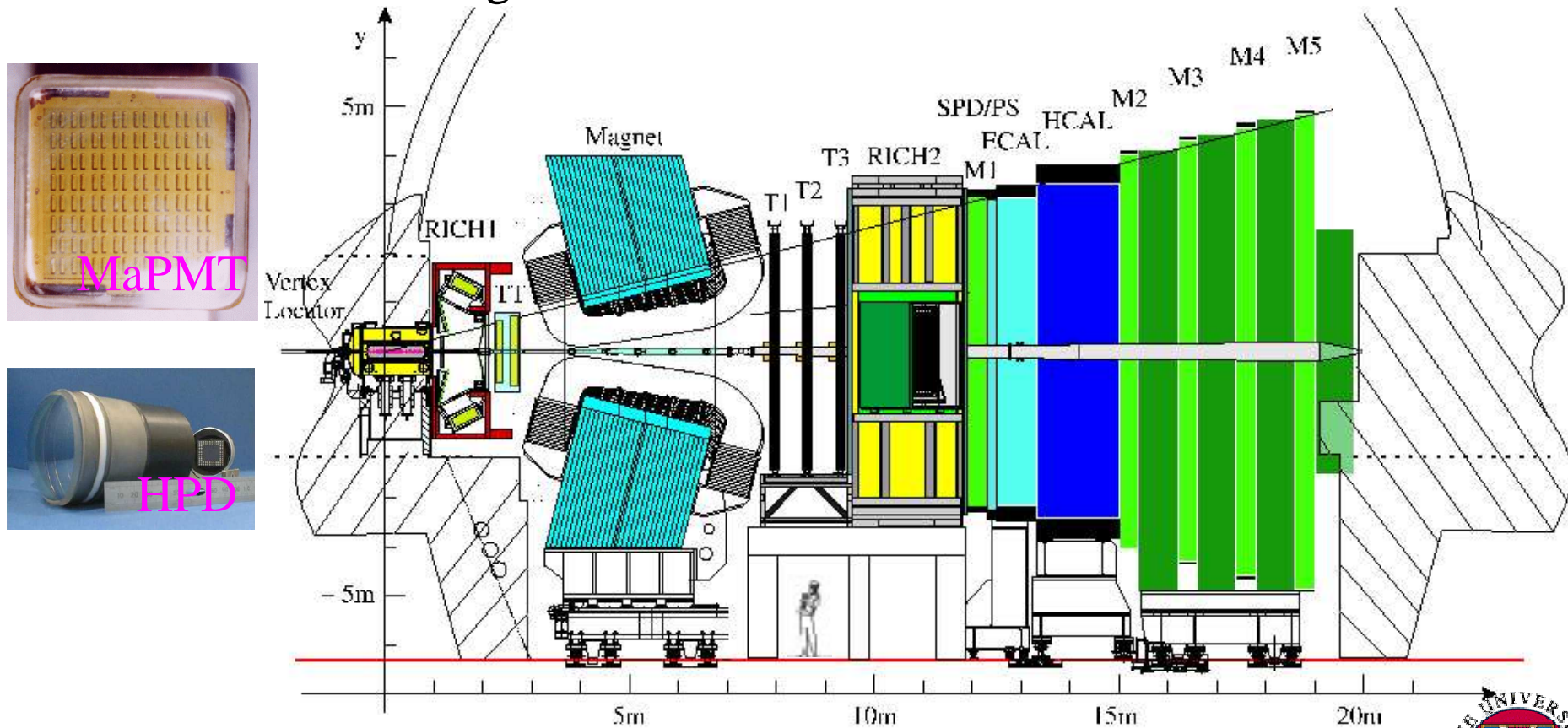
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MaPMTs and LHCb

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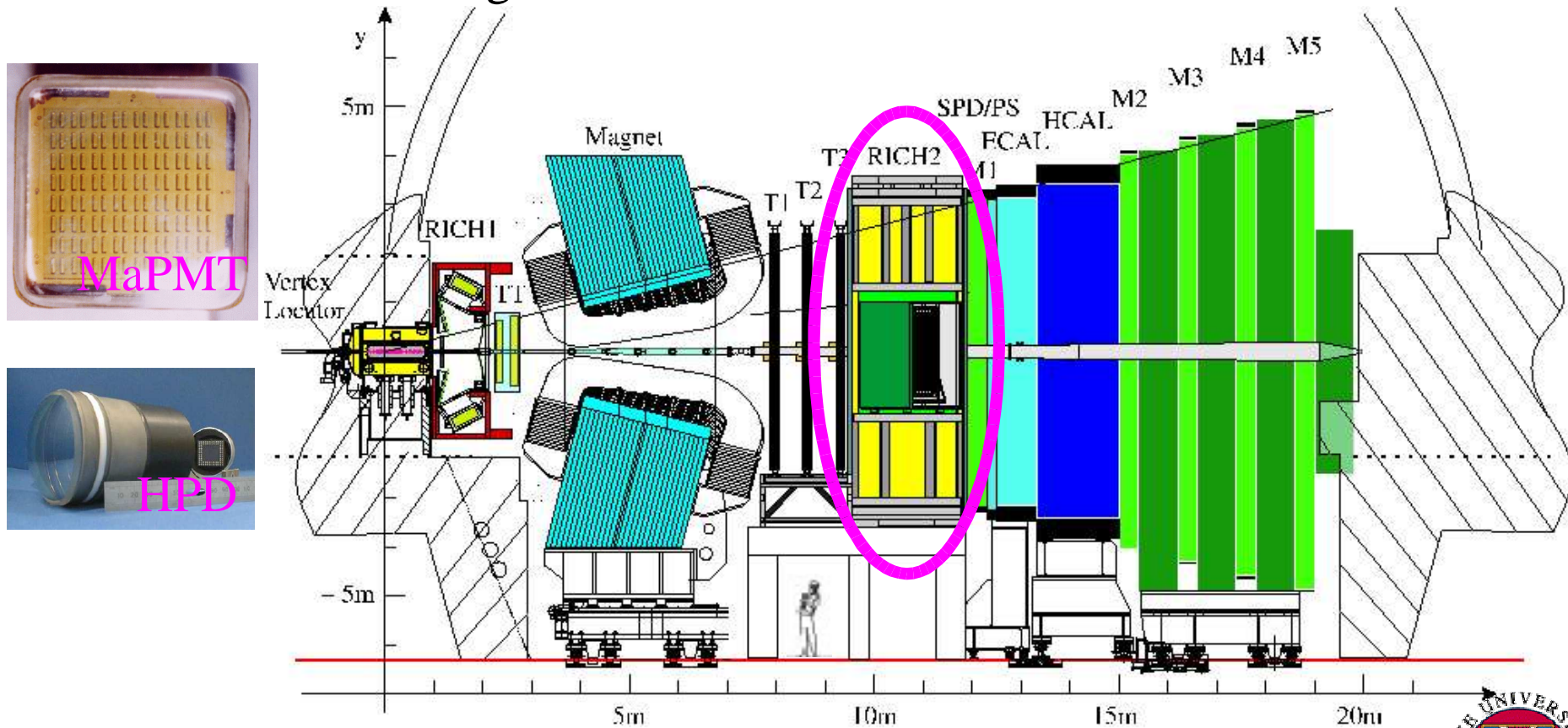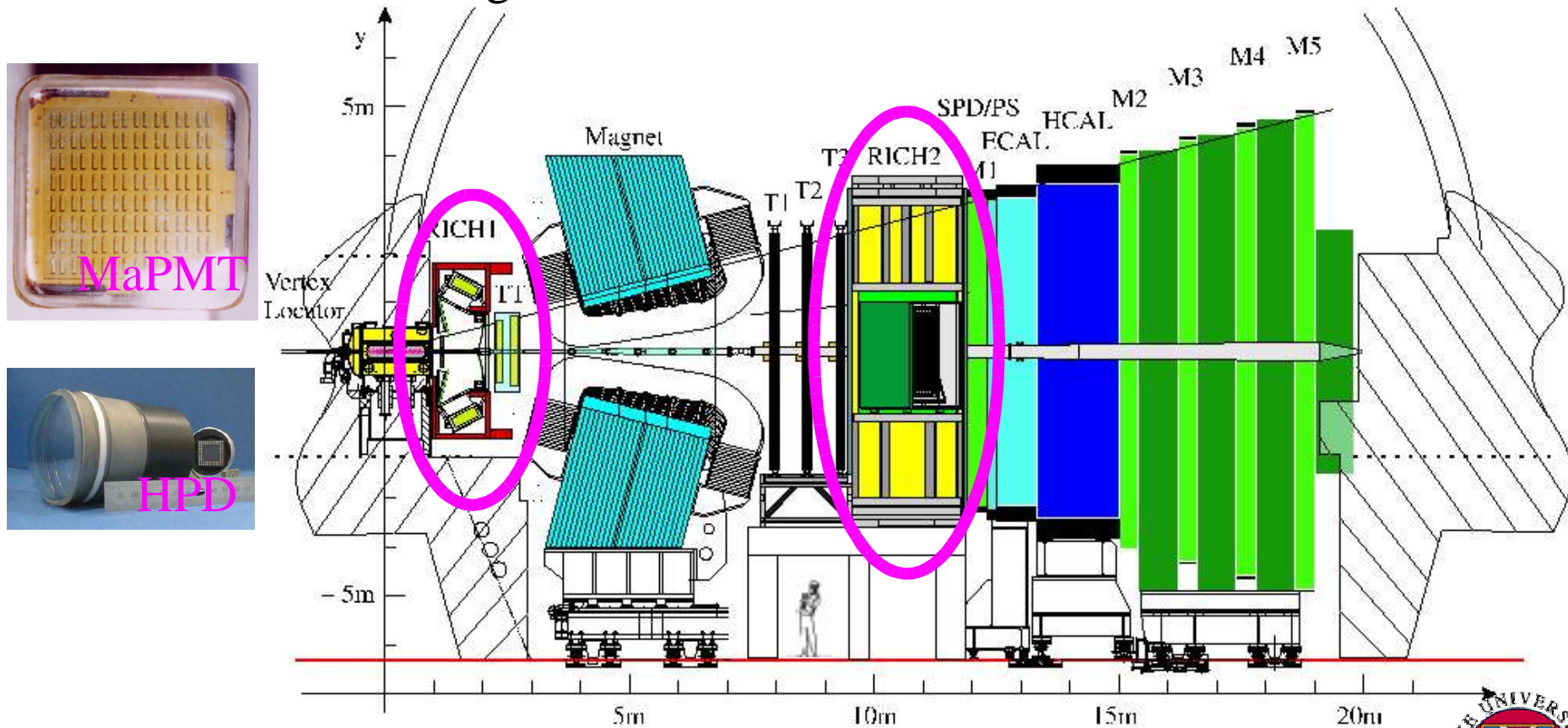
- 2 Photo detectors designs

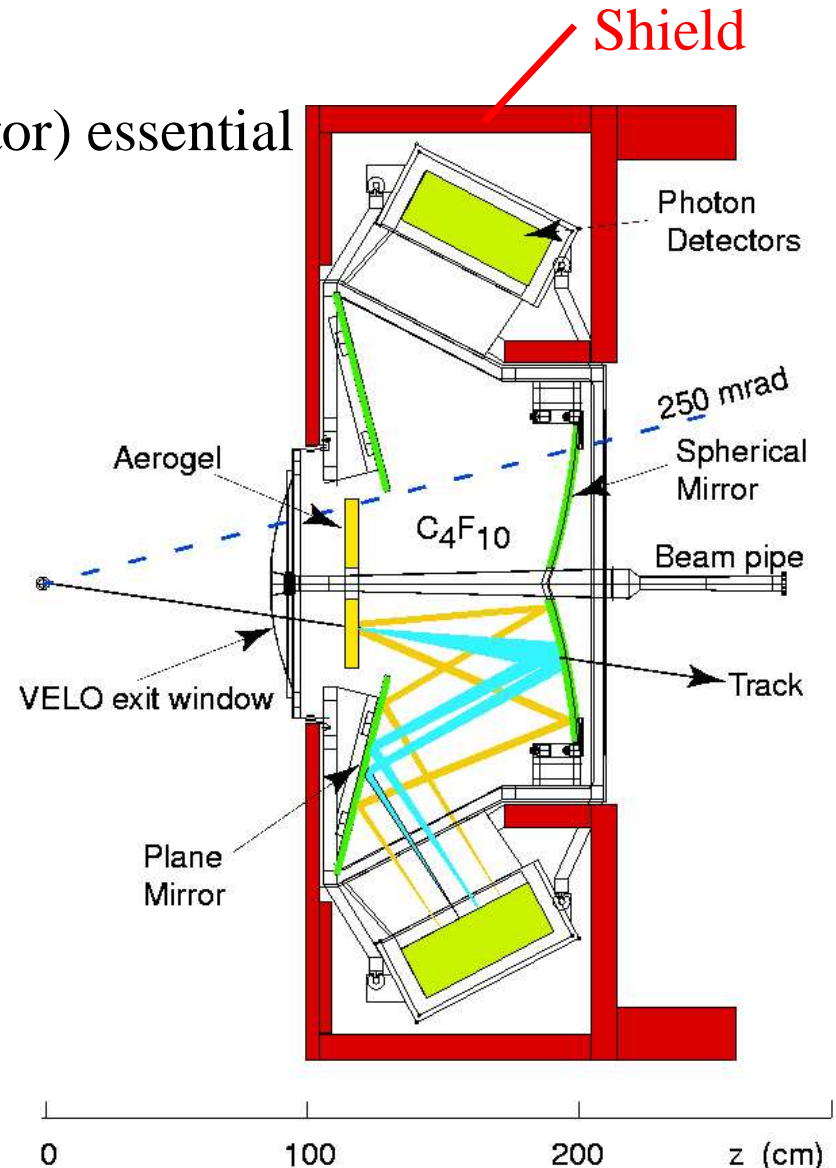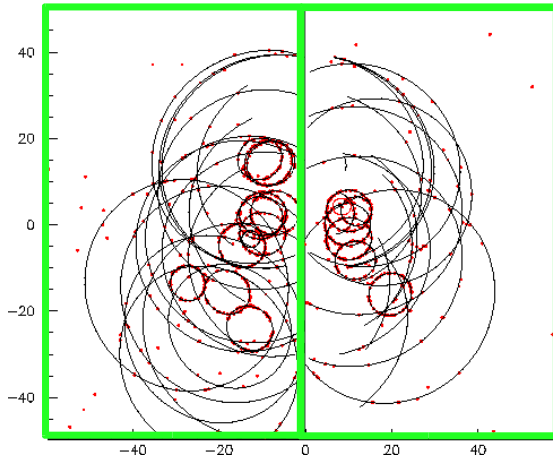# MaPMTs and LHCb

- LHCb: Large Hadron Collider beauty experiment

- Detector being build at CERN for the study of CP violation

- 2 Photo detectors designs

MaPMTs and LHCb

- RICH (Ring Imaging CHerenkov detector) essential

 for charged particles identification

  - single photon sensitivity
  - fast (<25ns) and low noise signal ratio
  - tolerance against magnetic fields (~2.5 mT)
  - radiation hard against a few krad/year
  - photo detector area: 2.9 m²

Photon Detectors

250 mrad

Aerogel

C₄F₁₀

Spherical Mirror

Beam pipe

VELO exit window

Track

Plane Mirror

MaPMTs and LHCb

- Example of a 3x3 MaPMT cluster with quartz lenses (testbeam data with ring reconstruction for over several thousands of events)
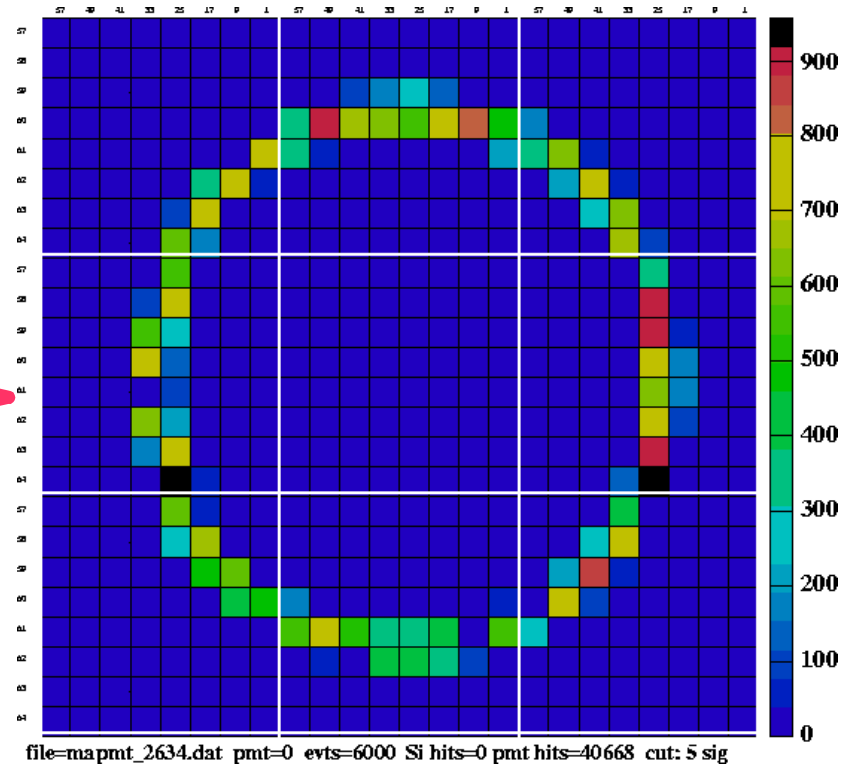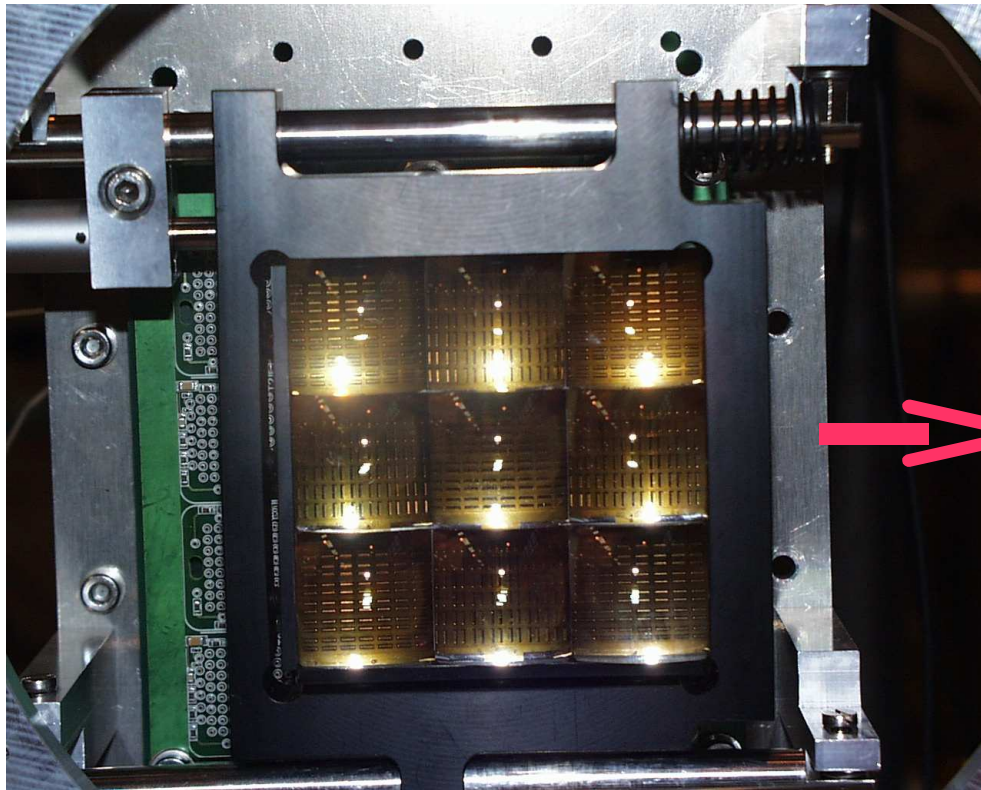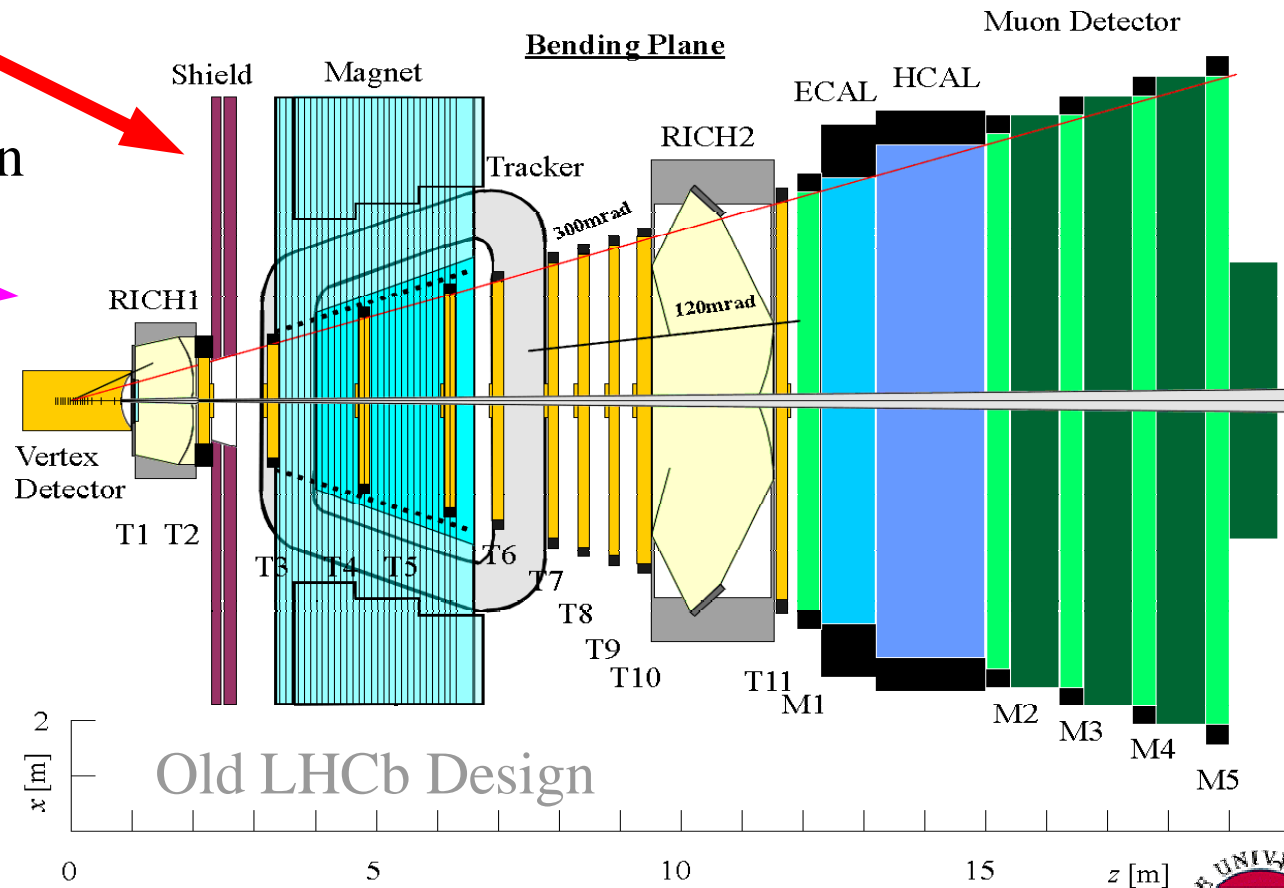
Why study the Effect of Magnetic field

- RICH1 is next to magnet with a 4Tm^{-1} Field

- Used to be a shield but removed to increase the path bending to improve triggering.
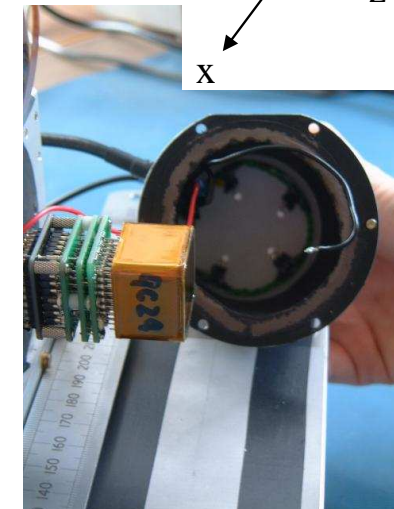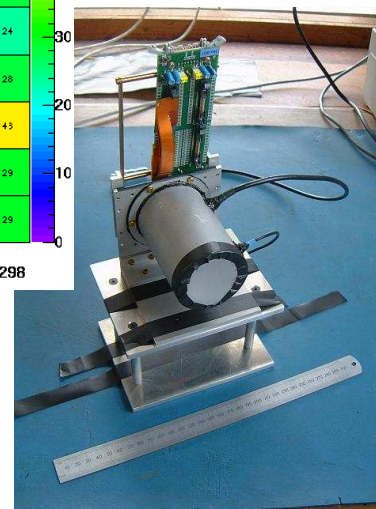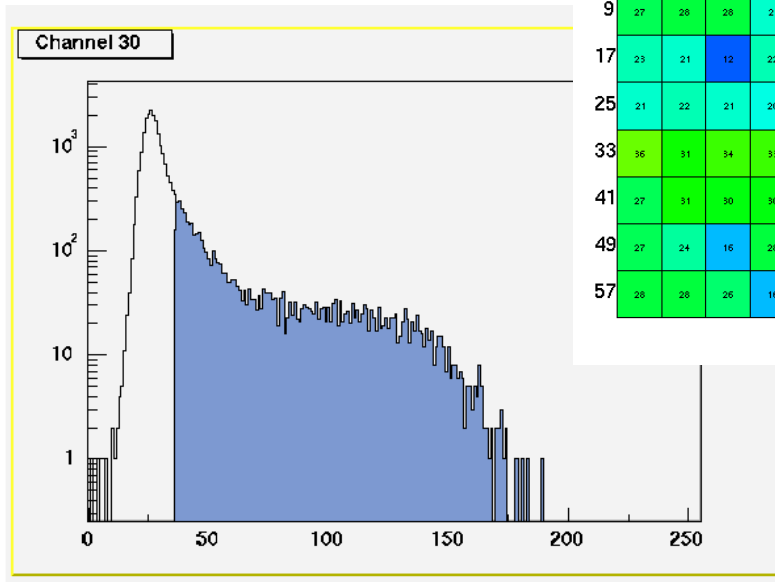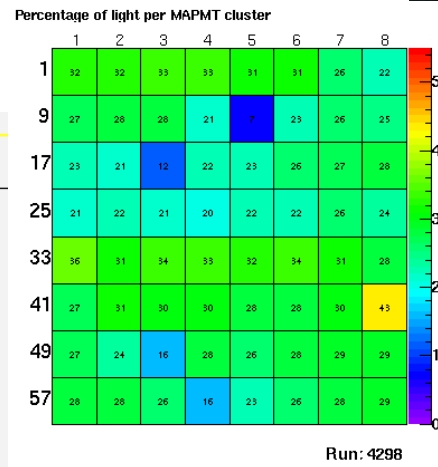
- Field in RICH1 region

  - 40mT

- Field inside RICH1

  - 2.5mT

Old LHCb Design
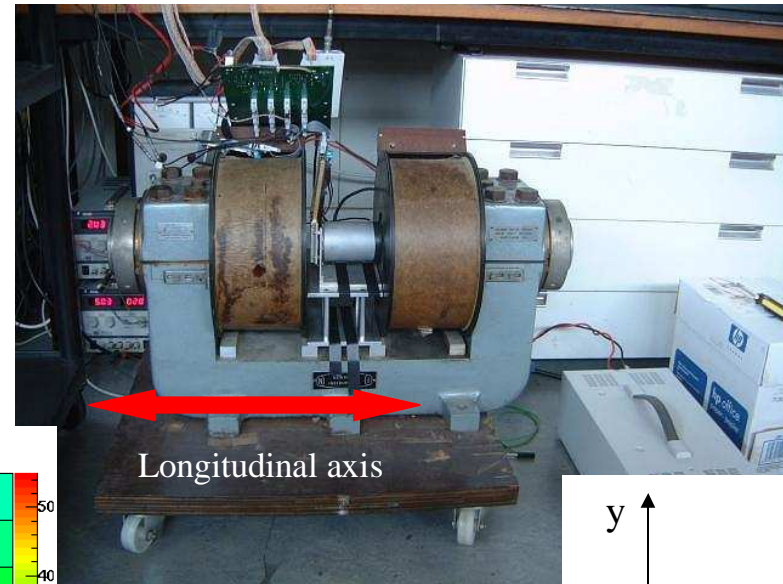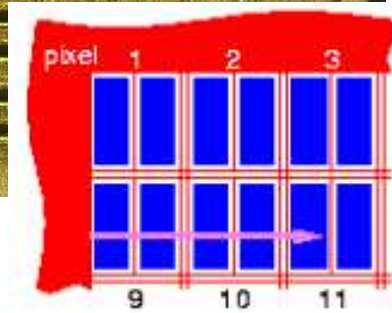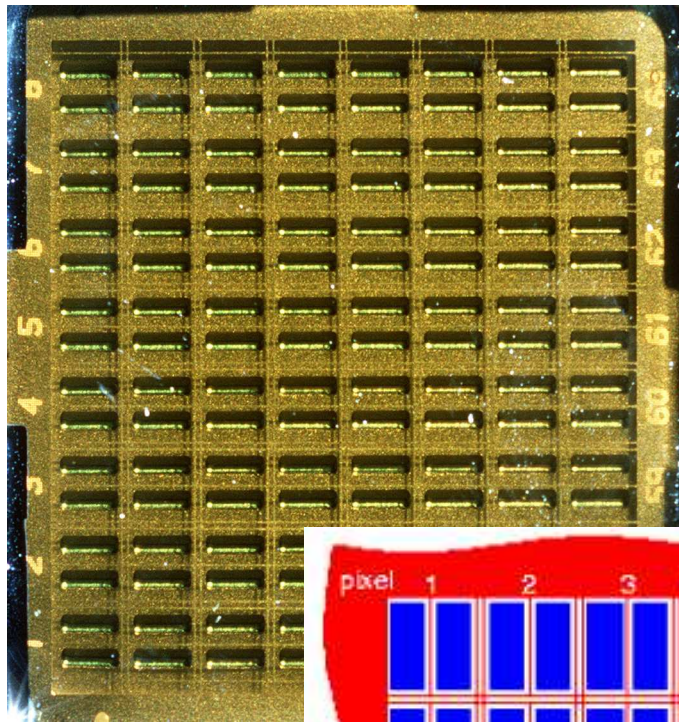
Setup and Data Acquisition

- A magnet : Field from (+/-) 0 - 35mT

- MaPMT in a light tight box

- Light source: 4 LED ring $\lambda = 430$nm

- High voltage: -1kV

- APVm readout system

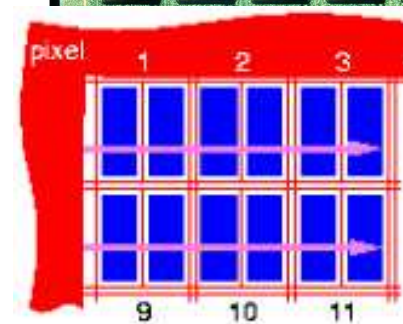Percentage of light per MAPMT cluster

	1	2	3	4	5	6	7	8
1	32	32	33	33	31	31	26	22
9	27	28	28	21	7	23	26	25
17	23	21	12	22	23	26	27	28
25	21	22	21	20	22	22	26	24
33	36	31	34	33	32	34	31	28
41	27	31	30	30	28	28	30	43
49	27	24	16	28	26	28	29	29
57	28	28	26	16	23	26	28	29

Run: 4298

Longitudinal axis

y
z
x

Channel 30
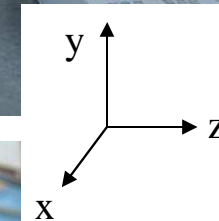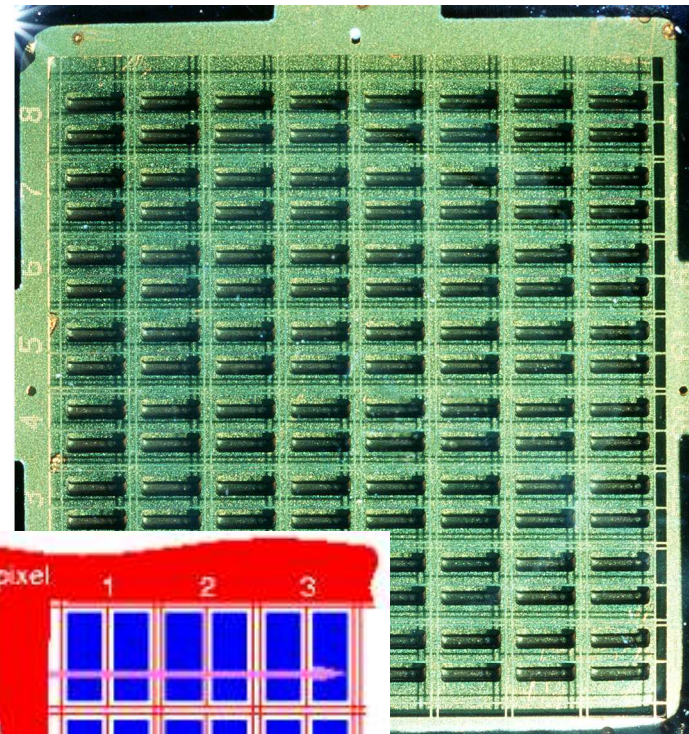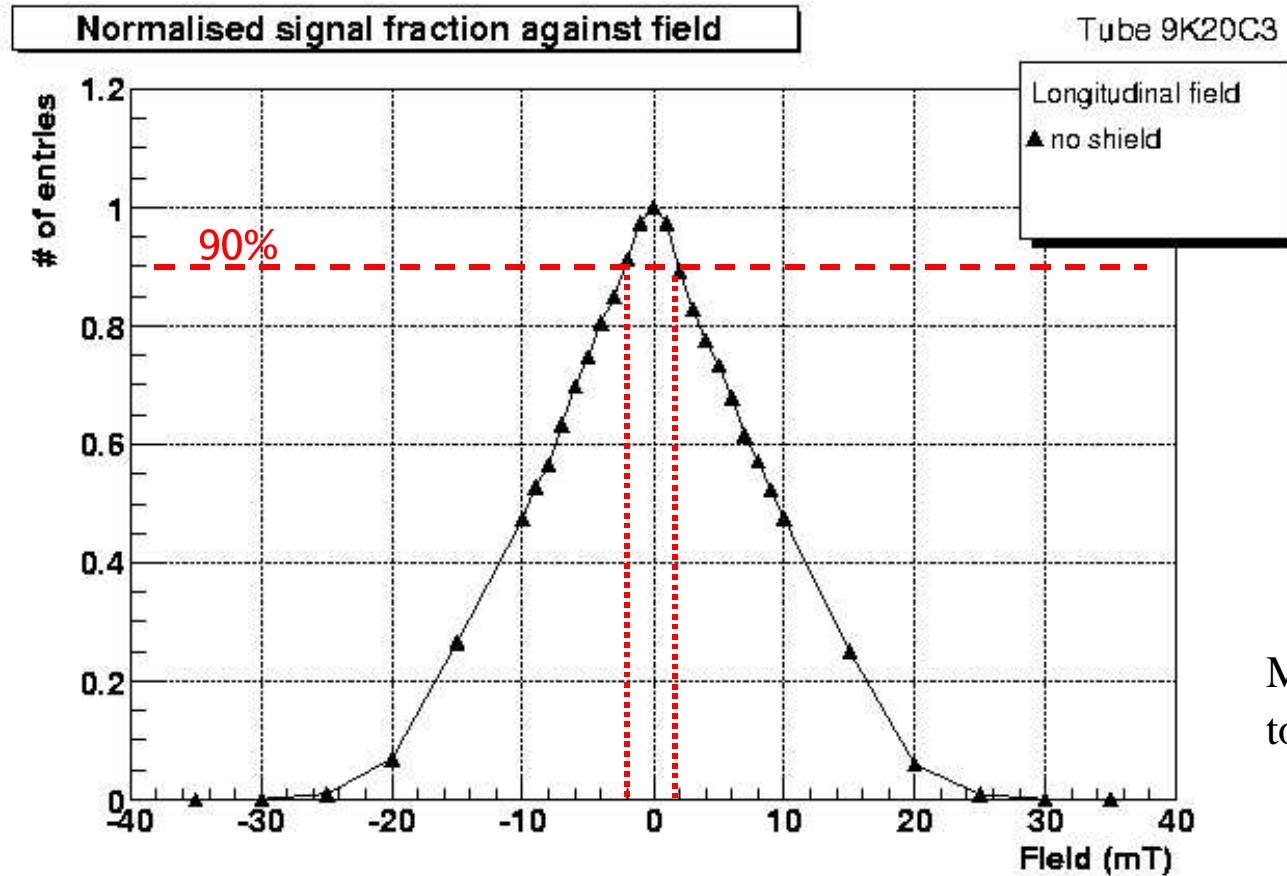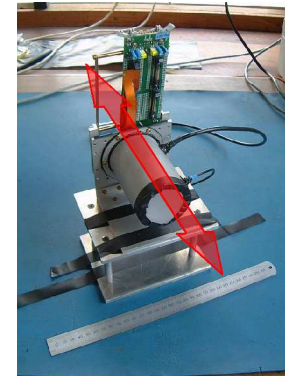
9C series: Old focusing

9K series: New focusing

- Improved homogeneity for edge pixels (better pulse height and collection efficiency)
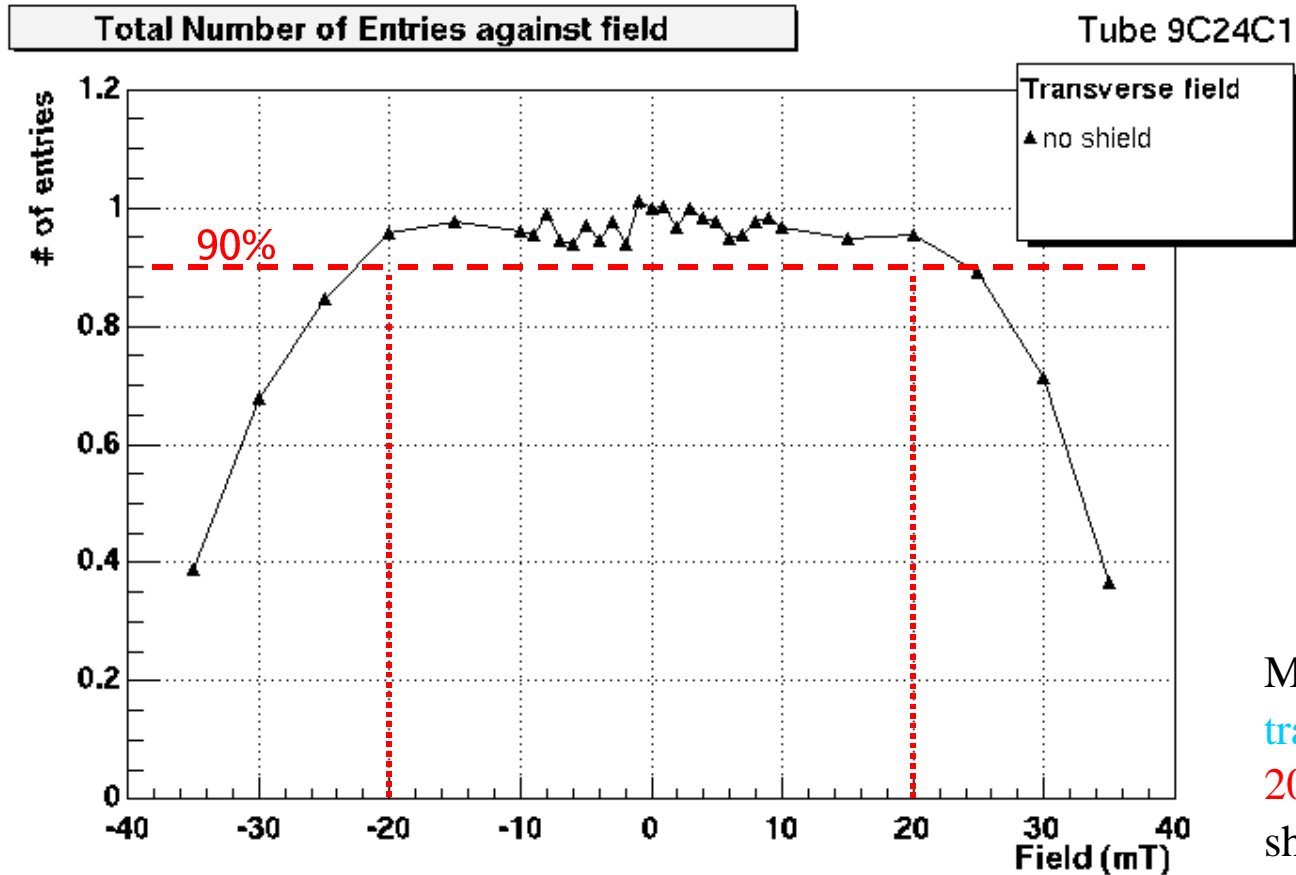
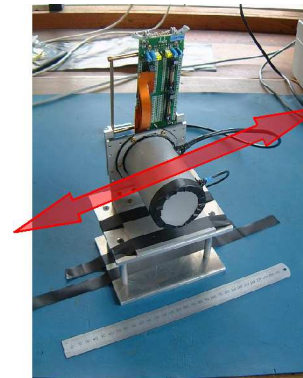# Longitudinal Magnetic Field

Normalised signal fraction against field — Tube 9K20C3

Longitudinal field
▲ no shield

90%

Normalised light yield in whole MaPMT

Longitudinal field in z-direction

MaPMT resists fields up to 2mT

Transverse Magnetic Field

Tube 9C24C1

Transverse field in x-direction

Normalised light yield in whole MaPMT

MaPMT insensitive to transverse fields up to 20mT (200 G) without shielding

Comparison Old vs New focusing

Total Number of Entries against field

Comparing two tubes without shielding

Tube 9C20A2
run 4366-4398

Tube 9K20C3
run 4843-4875

# of entries (y-axis), Field (mT) (x-axis)

Normalised light yield in whole MaPMT
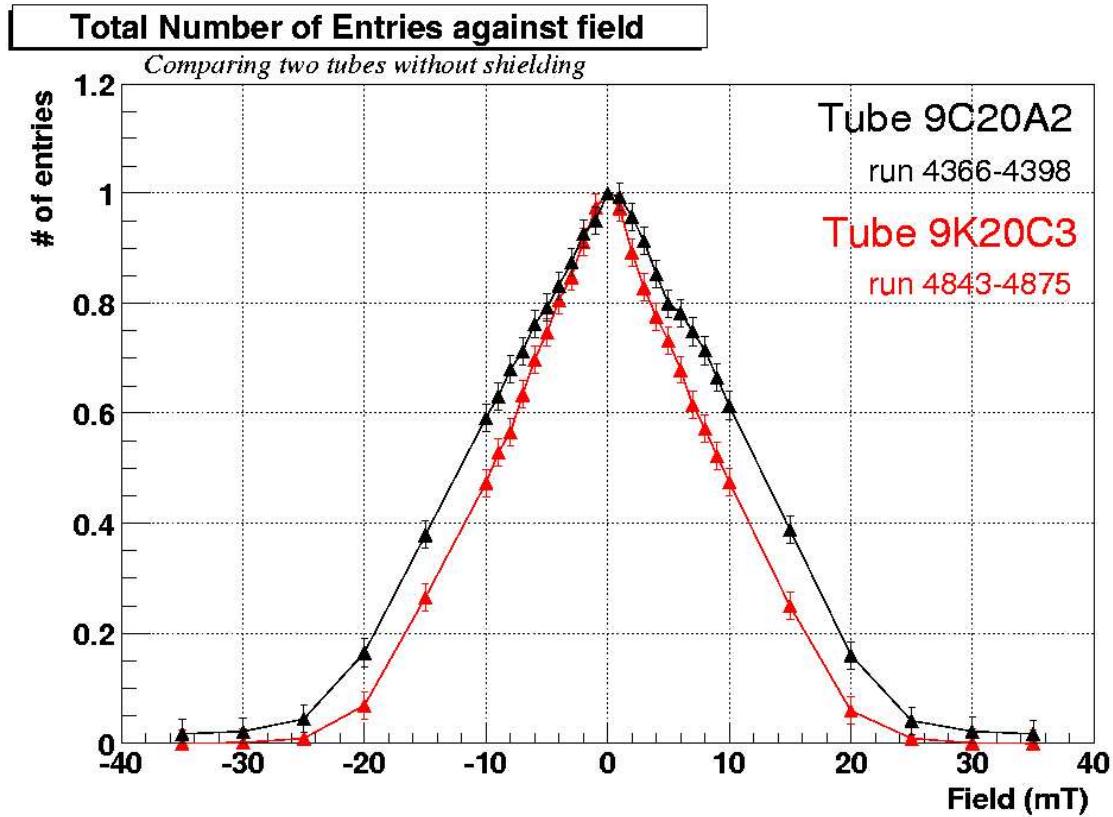
Longitudinal field in z-direction
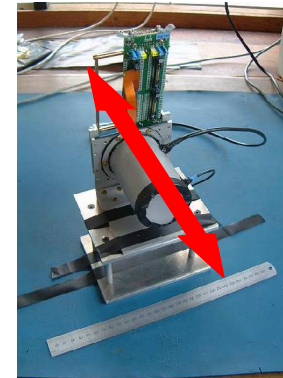
New focusing more sensitive to the field by ~ 10-20%

Colour Legend

- 1 mT
- 2 mT
- 3 mT
- 4 mT
- 5 mT
- 6 mT
- 7 mT
- 8 mT
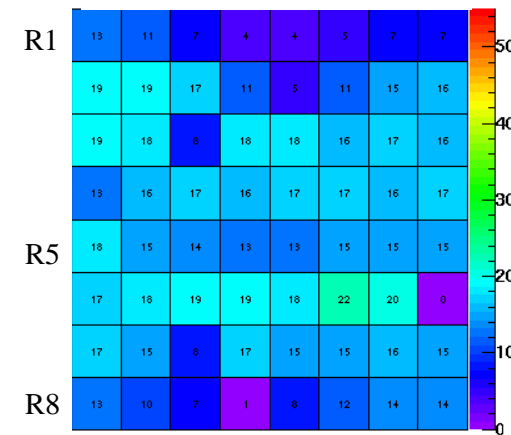- 9 mT
- 10 mT
- 15 mT
- 20 mT
- 25 mT
- 30 mT
- 35 mT

Conclusion

- Top and bottom row drop first
- 5th row population drops while side rows increases
- ~50% lost for edge rows at 3mT
- Column population decreases uniformly
- Same behaviour for tube 9K20C3 (new)
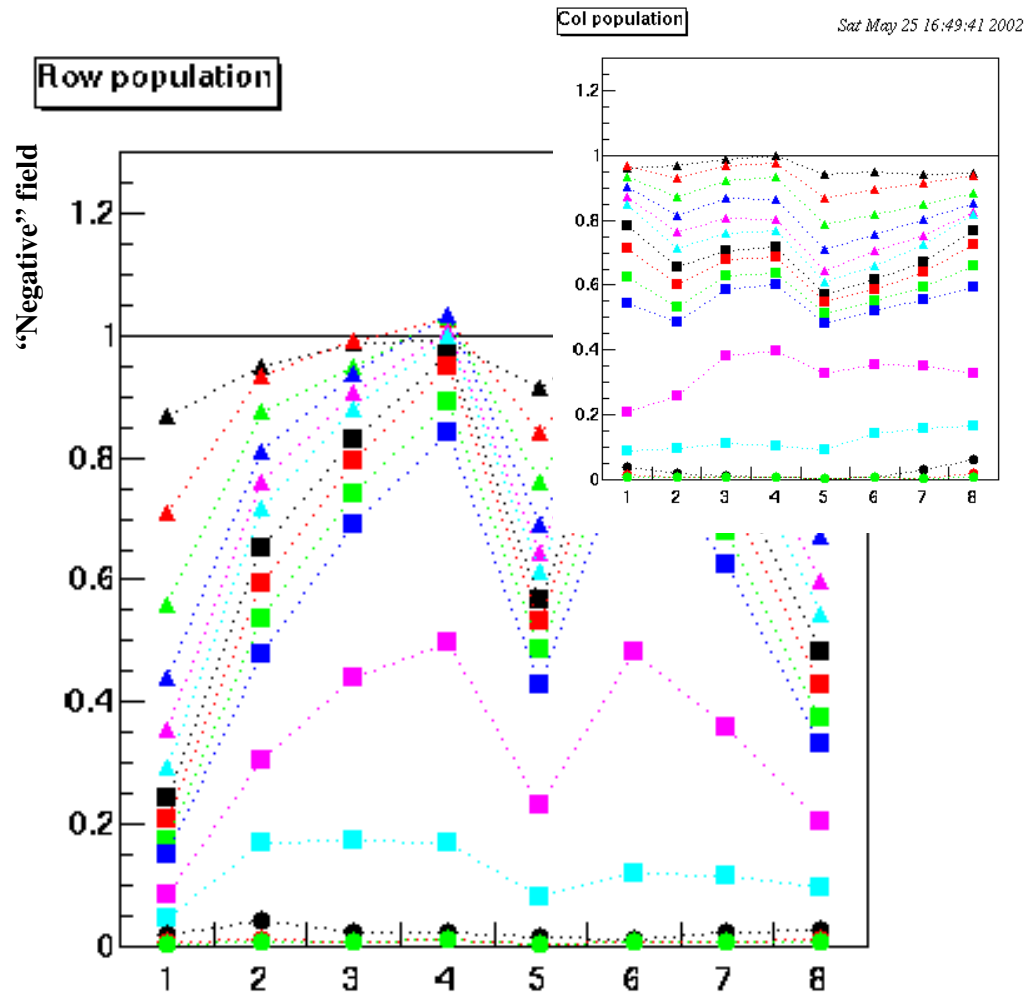
Distribution example at 6 mT

Colour Legend

□ 1 mT
□ 2 mT
□ 3 mT
□ 4 mT
□ 5 mT
□ 6 mT
□ 7 mT
□ 8 mT
□ 9 mT
□ 10 mT
□ 15 mT
□ 20 mT
□ 25 mT
□ 30 mT
□ 35 mT

Row population
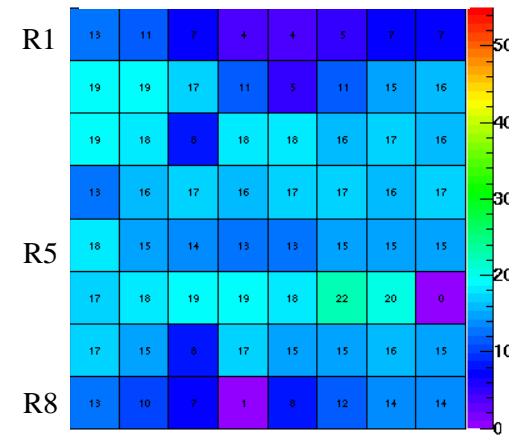

Col population   Sat May 25 16:49:41 2002
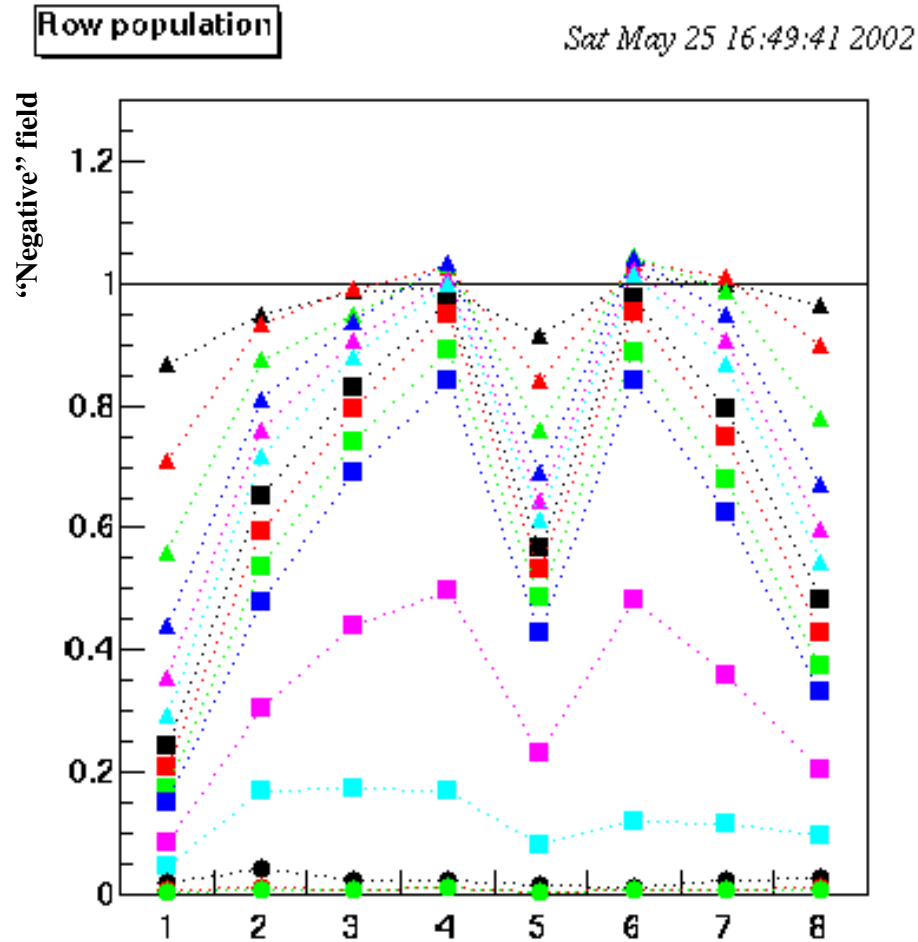
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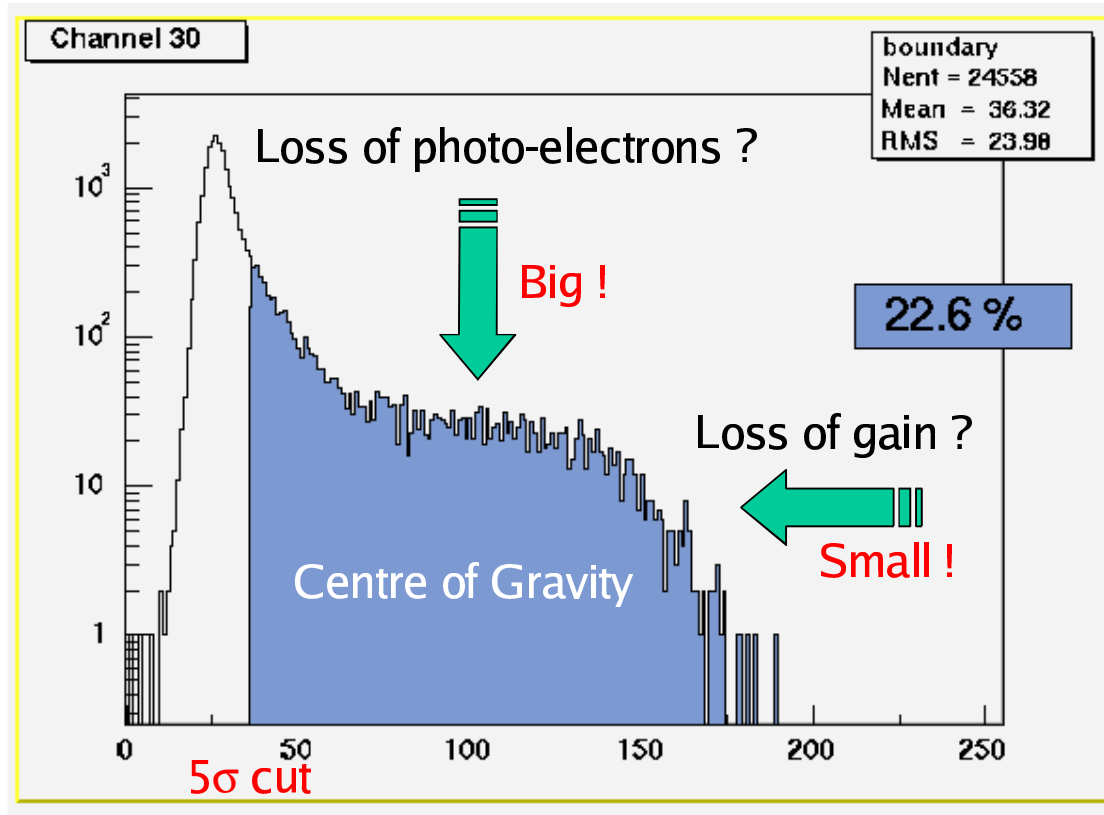Distribution example at 6 mT

Percentage of light per MAPMT cluster
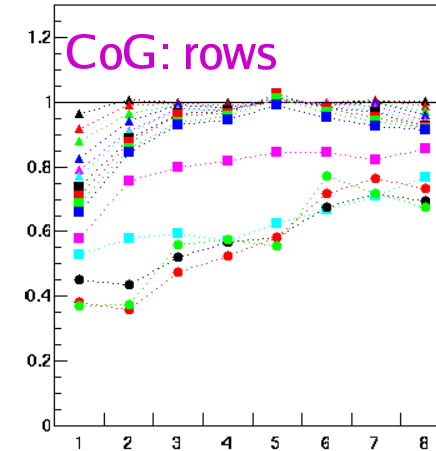
Run: 4389

Cause of the Losses

signal spectrum of single pixel
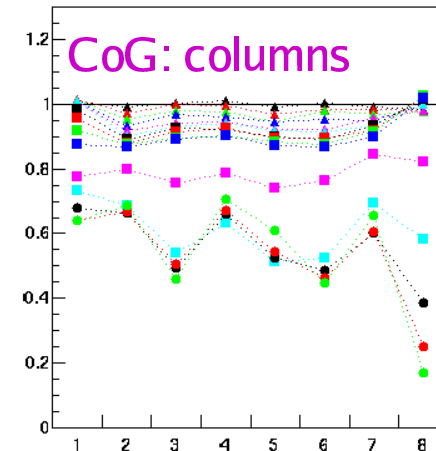
Cross Talk over Adjacent Channels

Row 4 against row5

Longitudinal field
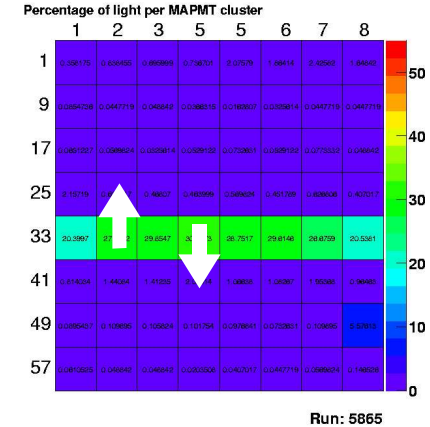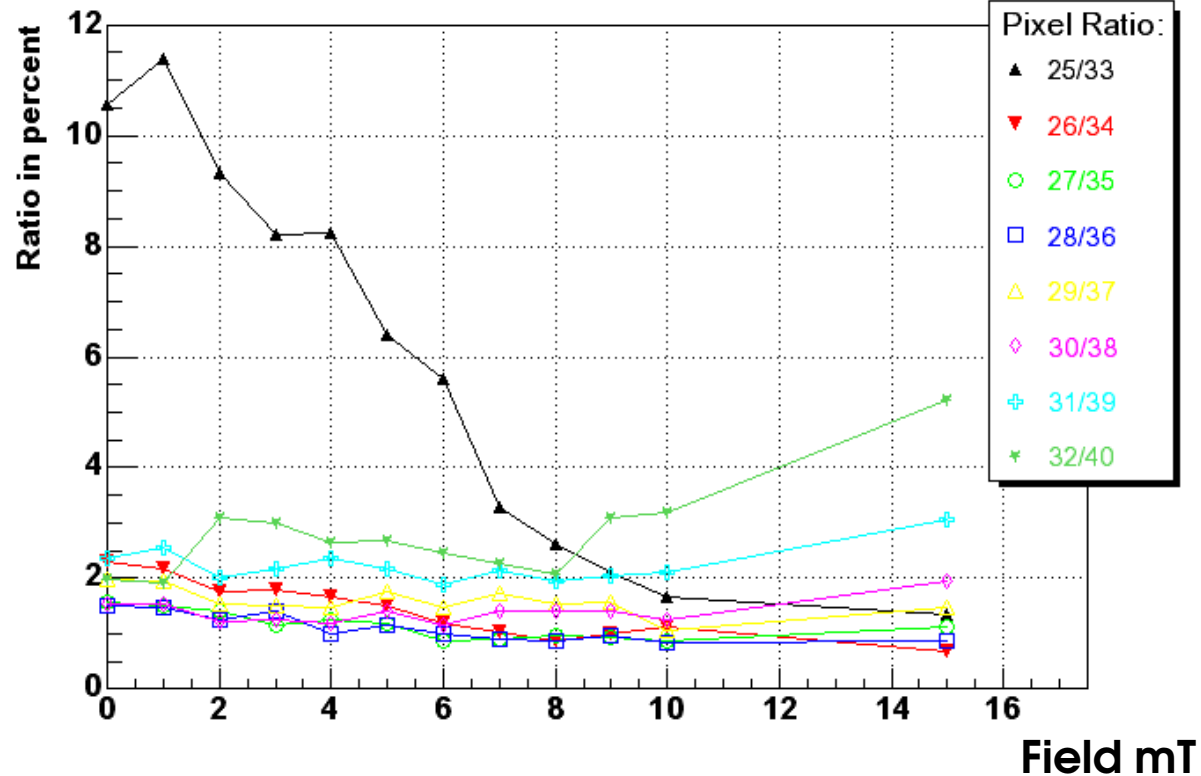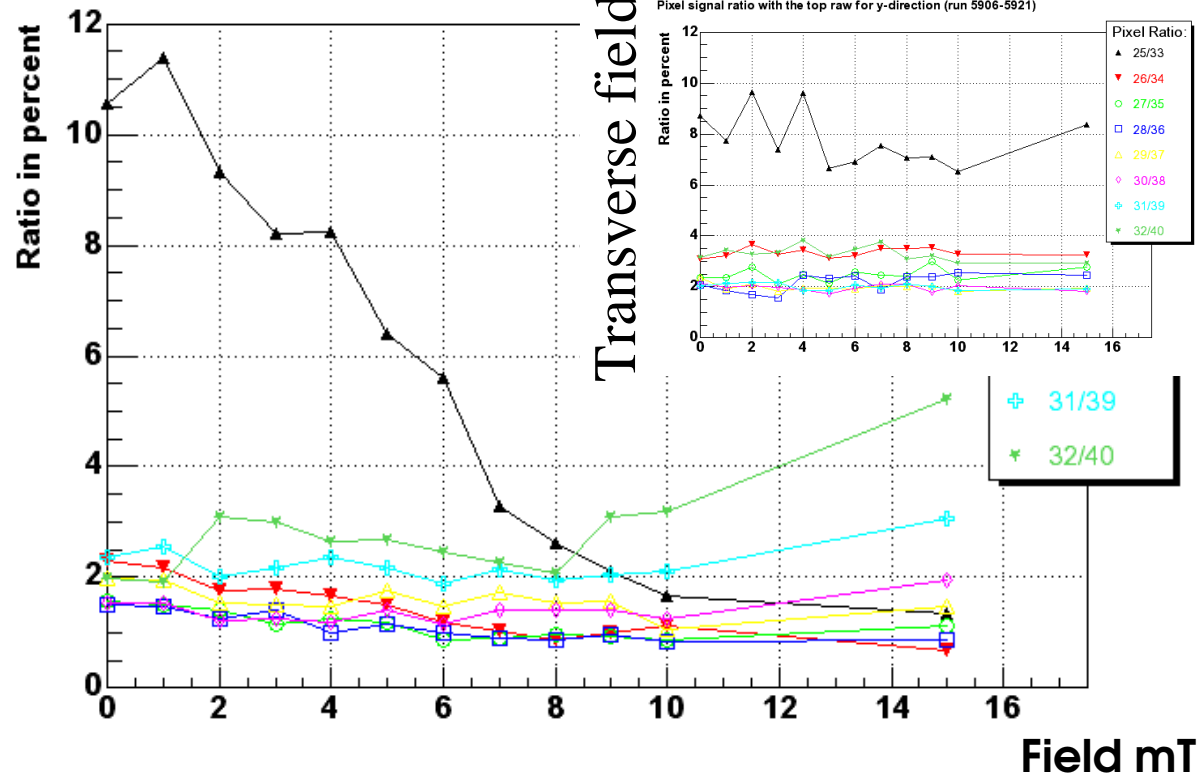
Conclusion:

- No Cross talk induced by magnetic field

Cross Talk over Adjacent Channels

Row 4 against row5

Conclusion:

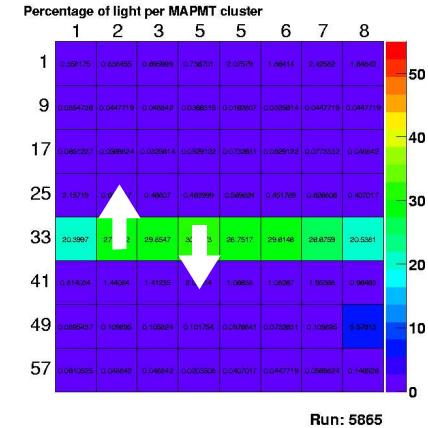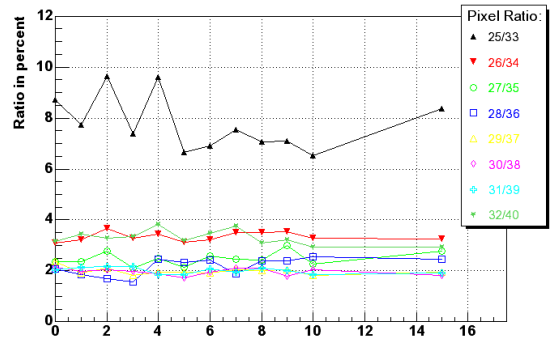- No Cross talk induced by magnetic field

Solution: Shielding with mu-metal

Normalised Signal Fraction Against Field — Tube 9C20A2

Legend:
- ■ no shield
- ▲ 13mm shield
- △ 13mm double shield
- ● 20mm shield
- ○ 20mm double shield

Old focusing

Normalised Signal Fraction Against Field — Tube 9C20A2 - zoom in

ZOOM-IN
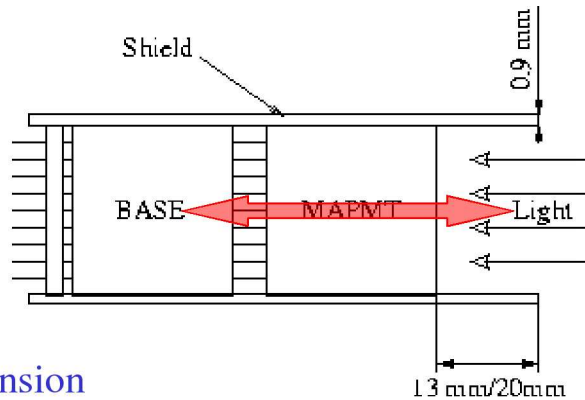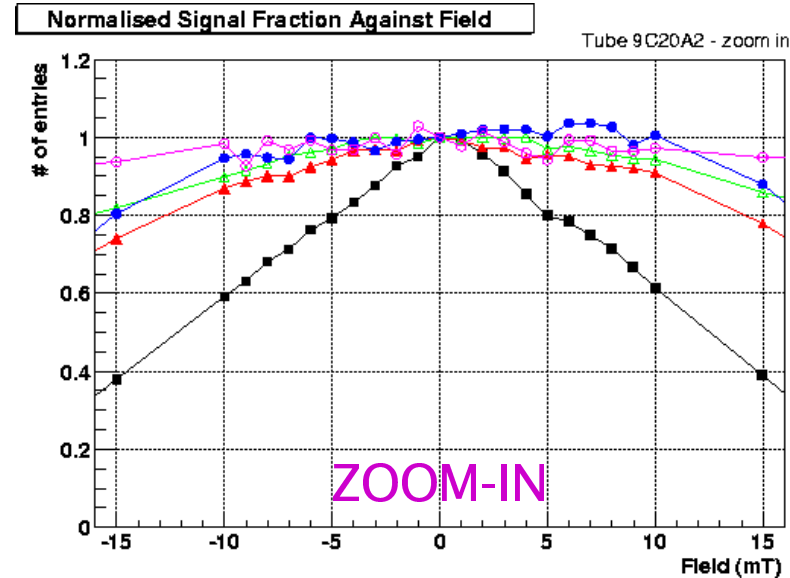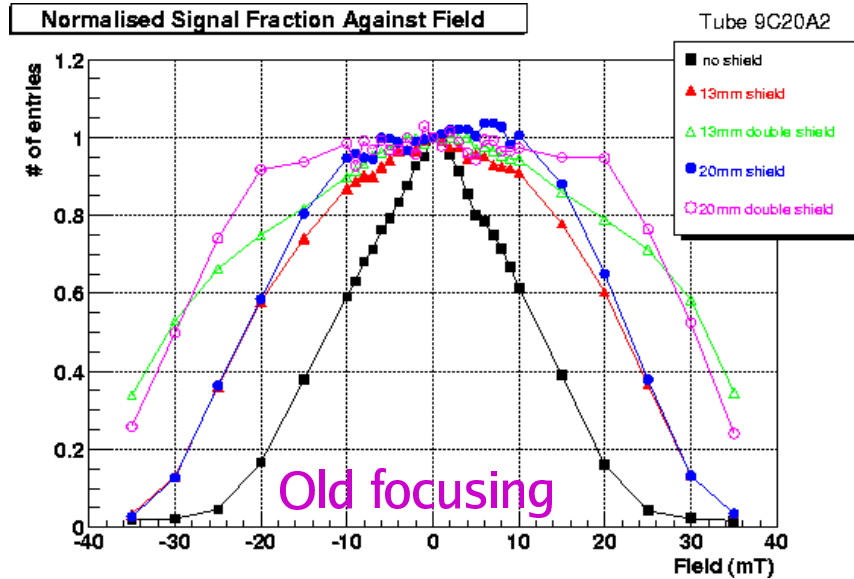
-metal shield:
0.9 mm thick
13 or 20 mm extension

- **Unshielded MaPMT**
  - ~2 mT   B longitudinal
    ~20 mT   B transverse
- **Single Mu-metal shield**
  - 0.9 mm thick, 13 mm extension
  - can handle ~8 mT B longitudinal

Conclusions

- Measured photon yield and CoG up to 35mT
  - Loss of gain? → Small effect (CoG)
  - Distortion of pattern? → No! (masked measurement)
  - Loss of photons? → Predominant effect !
- Loss of photons <10%:
  - ~2 mT   B longitudinal / ~8mT with shielding
  - ~20 mT B transverse

- New focusing more sensitive the magnetic the field by ~10%
- MaPMTs fullfill LHCb criteria by using mu-metal shield