The BTeV RICH front end electronics

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For the RICH Group

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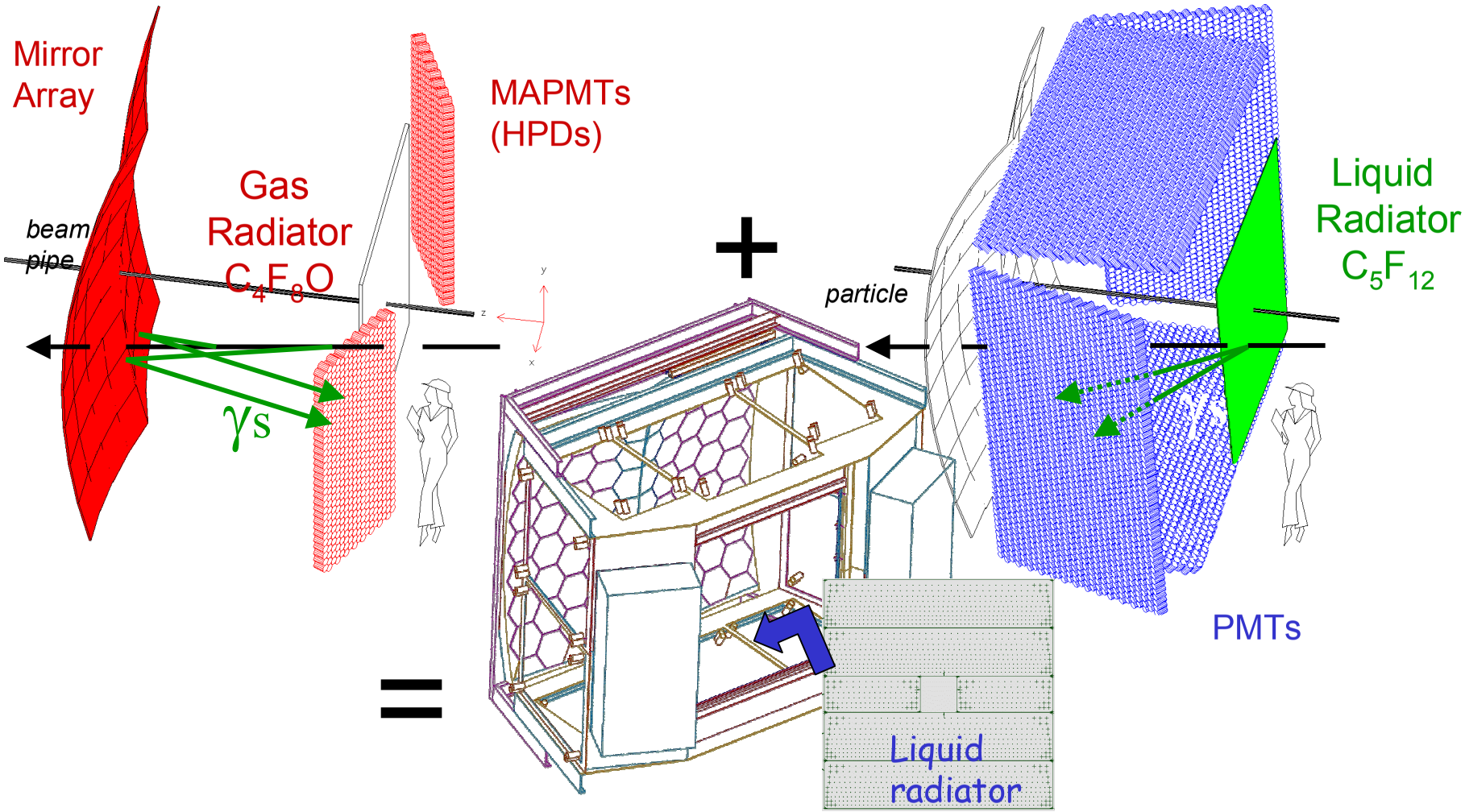
Introduction and overview

- BTeV is an experiment geared towards the exploration of new physics manifesting itself in charm and beauty decays
- Particle identification system is a key element in modern experiments studying heavy flavors and Ring Imaging Cherenkov (RICH) detectors are an optimal approach to achieve the desired particle separation (more in ***T. Skwarnicki's talk***)
- A front end electronics well matched to the experimental requirements (rate/occupancy…) and the chosen photon detectors is a key element in a successful implementation in any RICH detector.

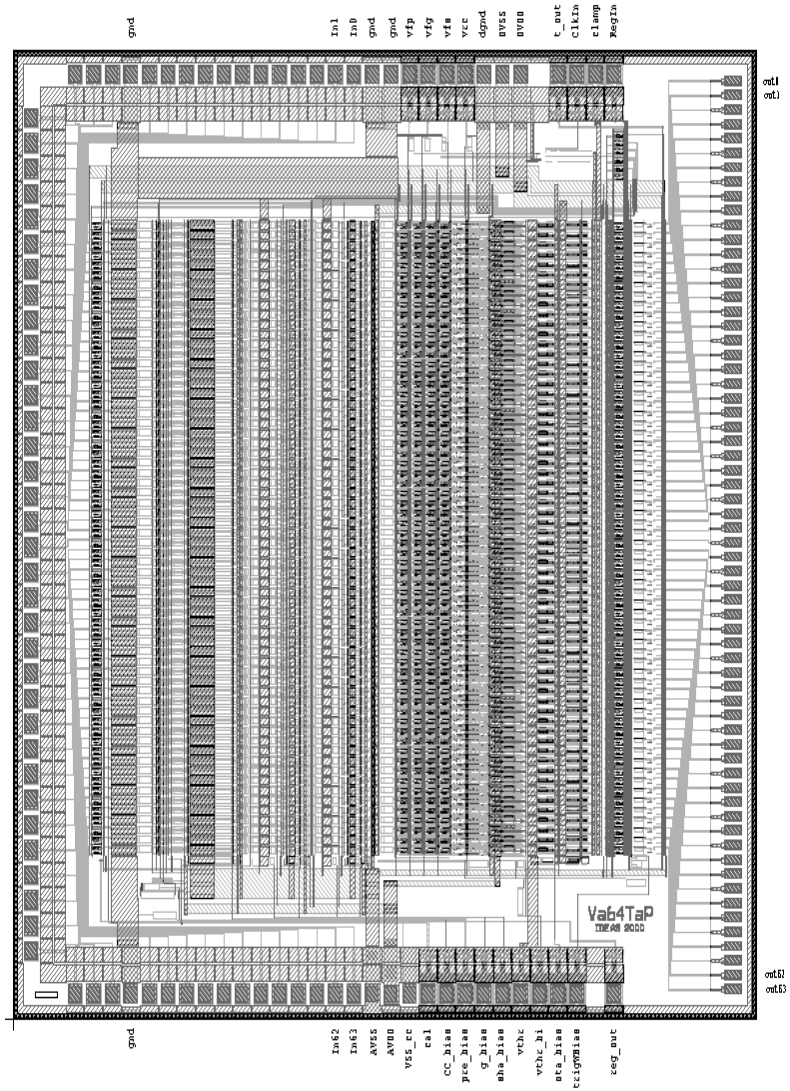
The BTeV RICH Detector

Mirror Focused Gas Radiator RICH

Proximity Focused Liquid RadiatorRICH



Photon detector front end ASIC



- FRONT END ASIC must
  - Noise matched to the dynamic range of the signal to be detected:
    - Low noise for HPD applications (≤ 500 e^-)
    - Moderate noise (1000-2000 e^-) for MaPMT and HPD applications
  - Dynamic range suitable for the specific application:
    - HPD signal 5,000 e^-
    - PMT medium dynamic range (~10^5)
    - PMT medium dynamic range (~10^6)
  - On chip sparsification
  - Data push architecture
  - Parallel digital readout to allow time stamping with beam crossing number

ASIC Functional Description

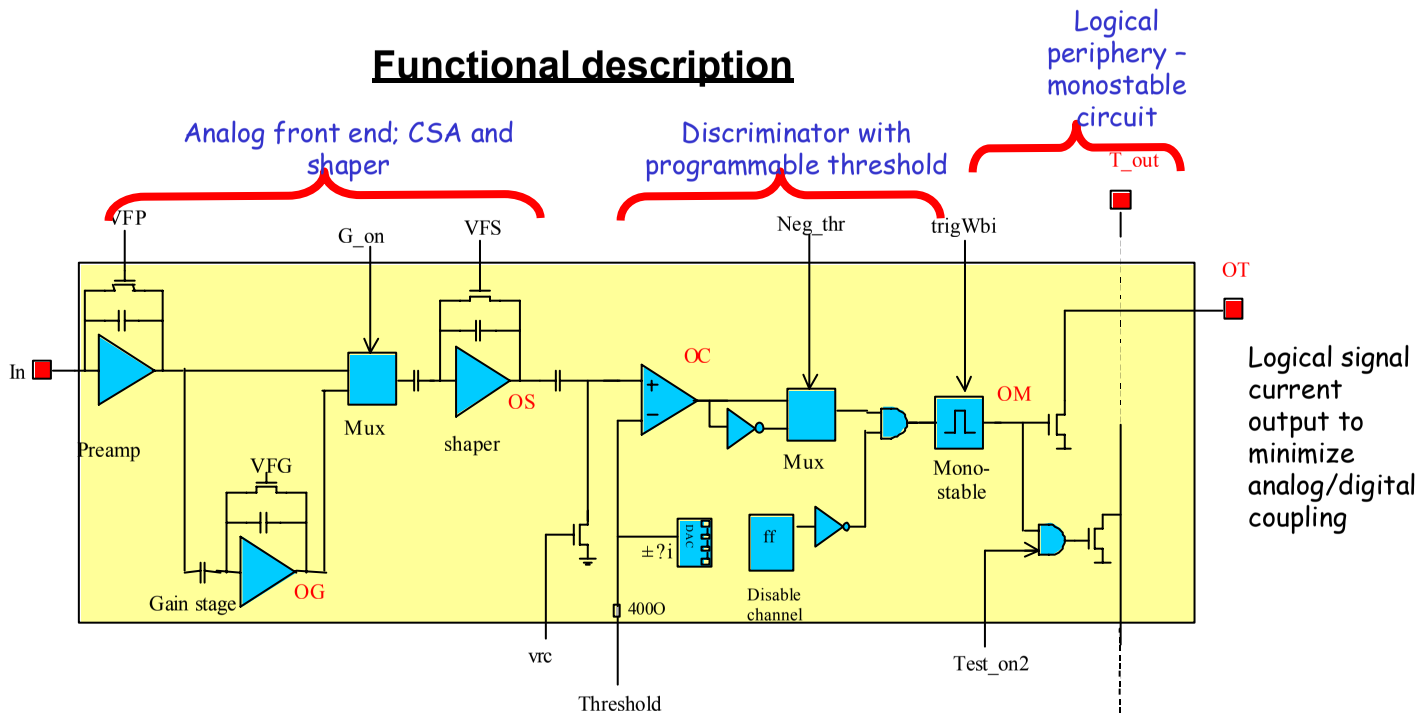


Fig 5. VA64Tap2 Channel Architecture. The gain stage will be removed.

The Va64Tap channel is shown in the figure above. After the preamplifier, the signal path is split in two. Depending on the setting of the global control bit ìg_onî, the input of the shaper is connected to either

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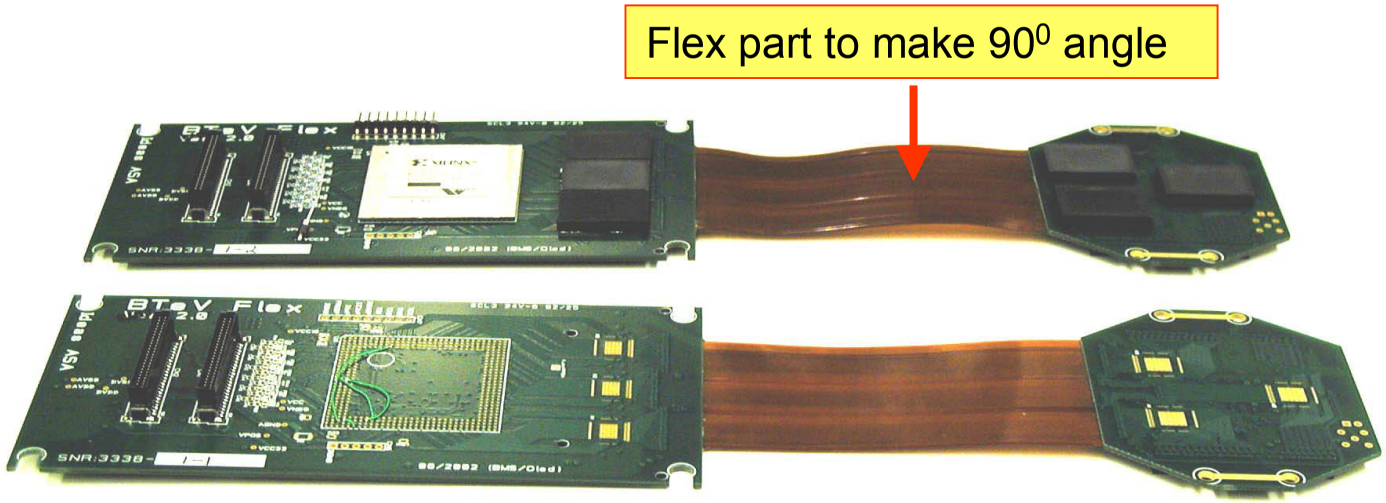
Some key technology parameters

- Process: 0.8 μm N-well CMOS, double-poly, double metal. Migrating to 0.35 μm CMOS
- Die size: 5605 μm x 5380 μm
  Thickness: ~ 600 μm
- Input bonding pads: Single row on three sides.
  Pad size: 90 μm x 90 μm
  Pad pitch: 140μm (see. fig. 2)
- Output pads: Single row on one side.
  Pad size: 50 μm x 120 μm
  Pad pitch: 80 μm (see fig. 2)
- Control and power pads: Single row on upper and lower side.
  Pad size: 90 μm x 90 μm
  Pad pitch: 140 μm (see fig. 2)

Brief history of R&D work

- PROTOTYPING STEPS:
  - 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
- These devices are based on the data driven ASICs developed for x-ray applications (VATAP).

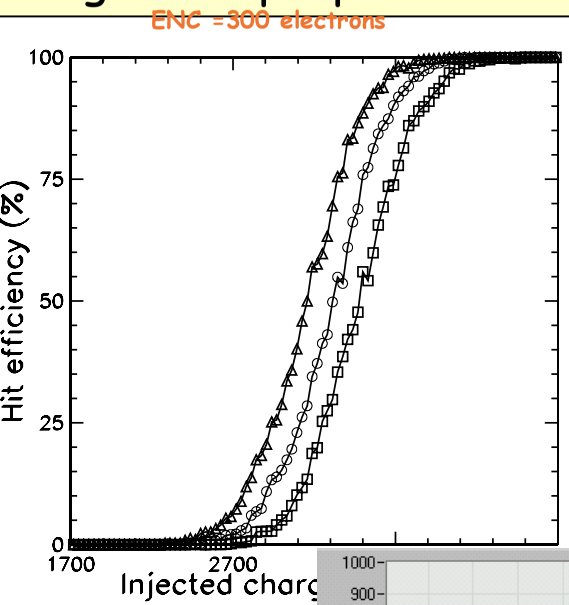
VA-BTeV Front-end Hybrids

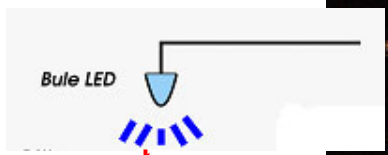


- 16 board characterized in standalone electronics test bench and with light source (blue LED) attached to BTeV HPD

HPD Readout Electronics tests

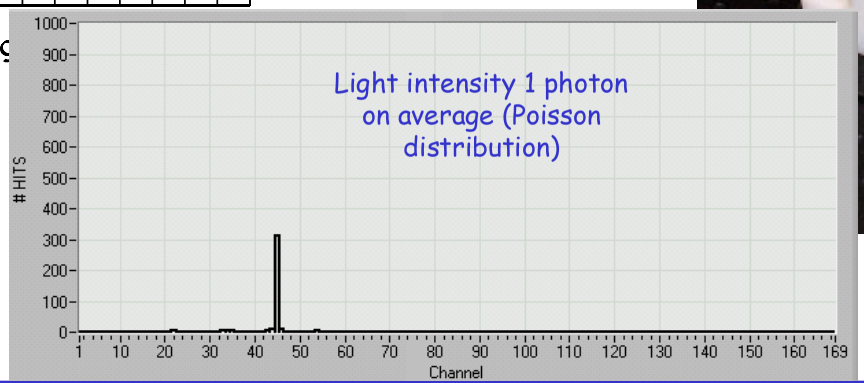
- ~500 *e* noise level be achieved
- Readout is binary (ON or OFF)
- 2nd iteration: 1 analog test channel for diagnostic purposes

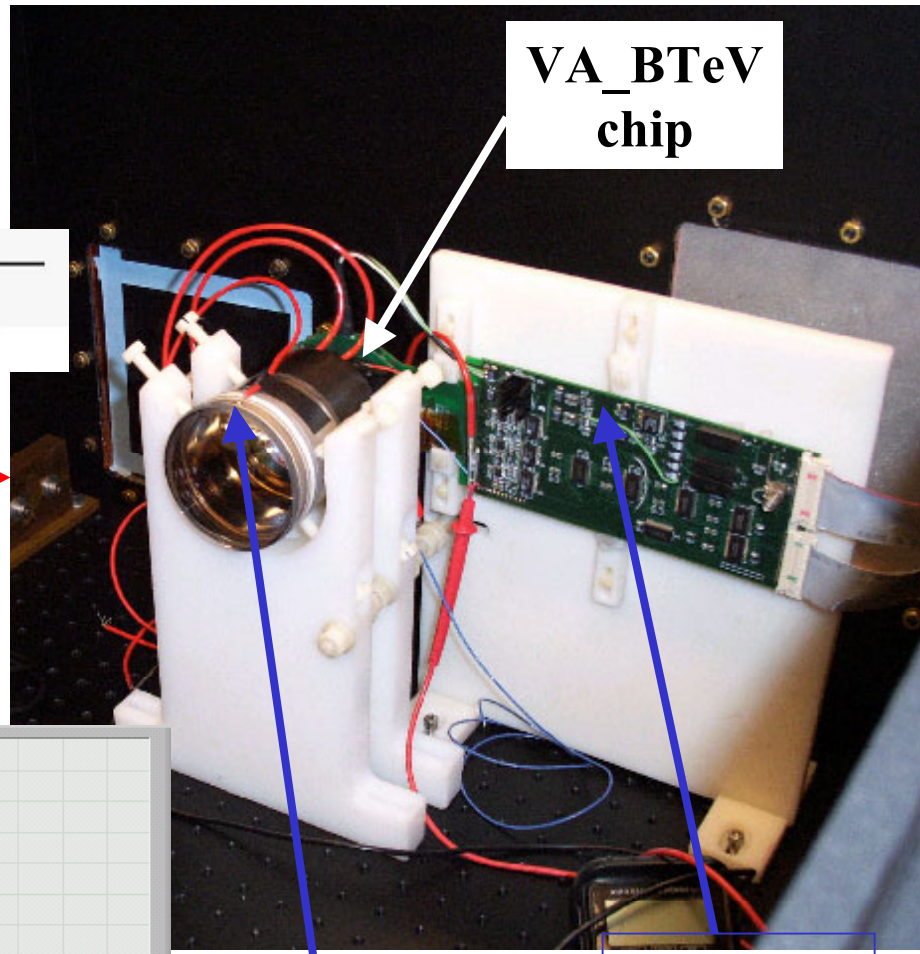




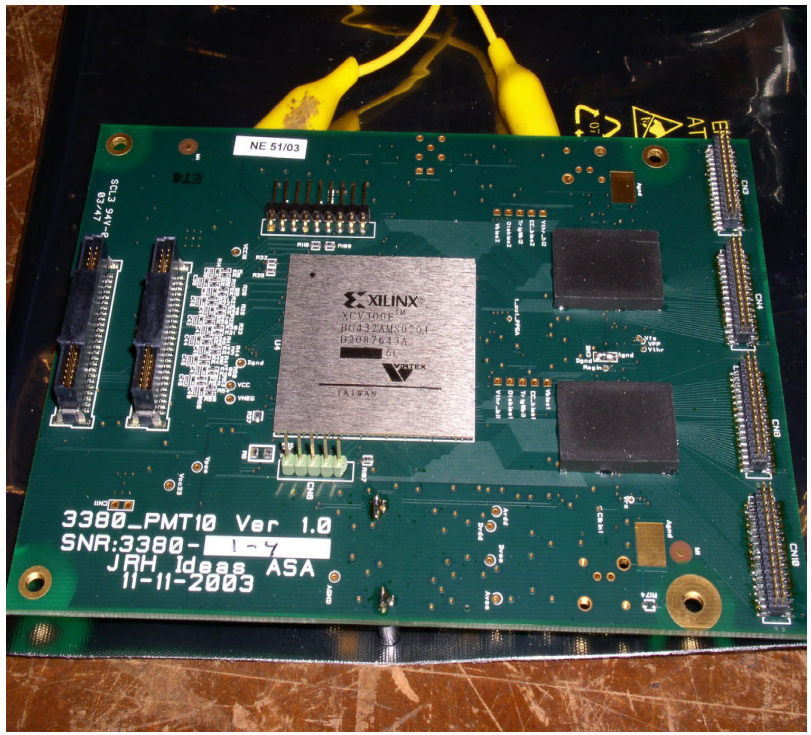
Optical fiber

Electronics response to light injected on a single pixel



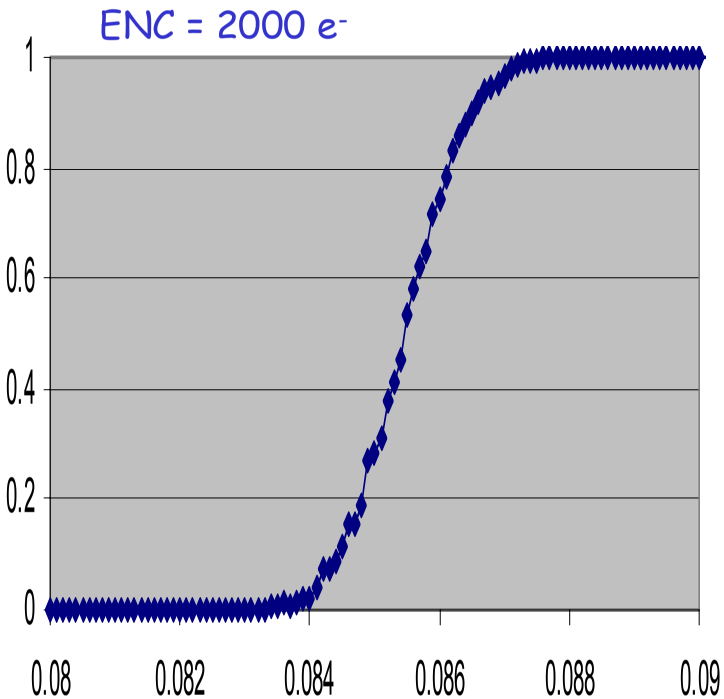


The VA_PMT1 ASIC and Hybrid

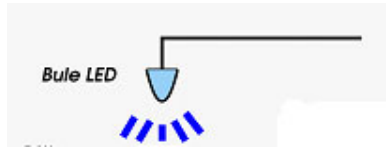


- Developed for the MaPMT test beam run
- New ASIC has higher dynamic range (tuned for most probable value 10^6 e^- and relatively long tail below this charge)
- Hybrid chip carrier implemented on standard PC board.

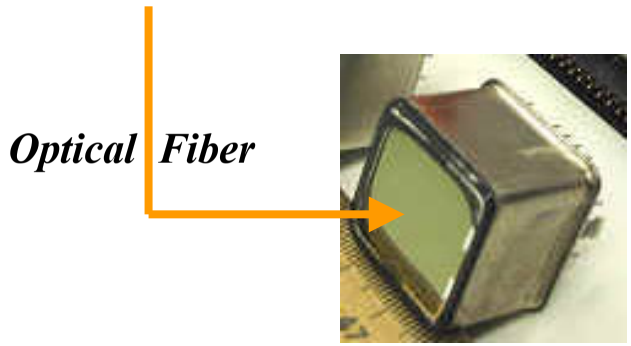
Characterization in the lab

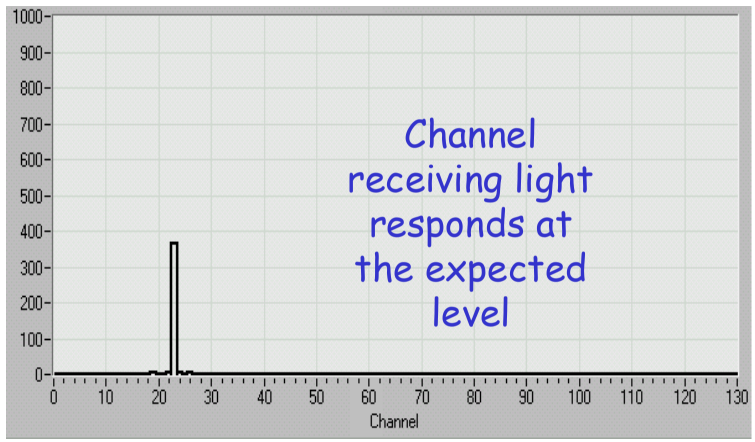


Threshold scan established expected noise performance



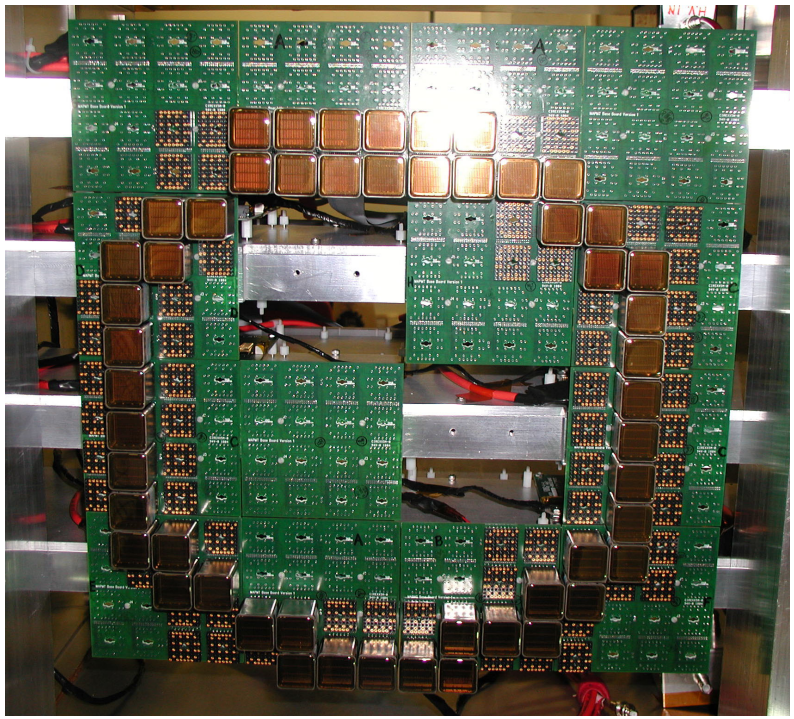
Current turned down to have a mean light intensity of a single photon (photon counting)

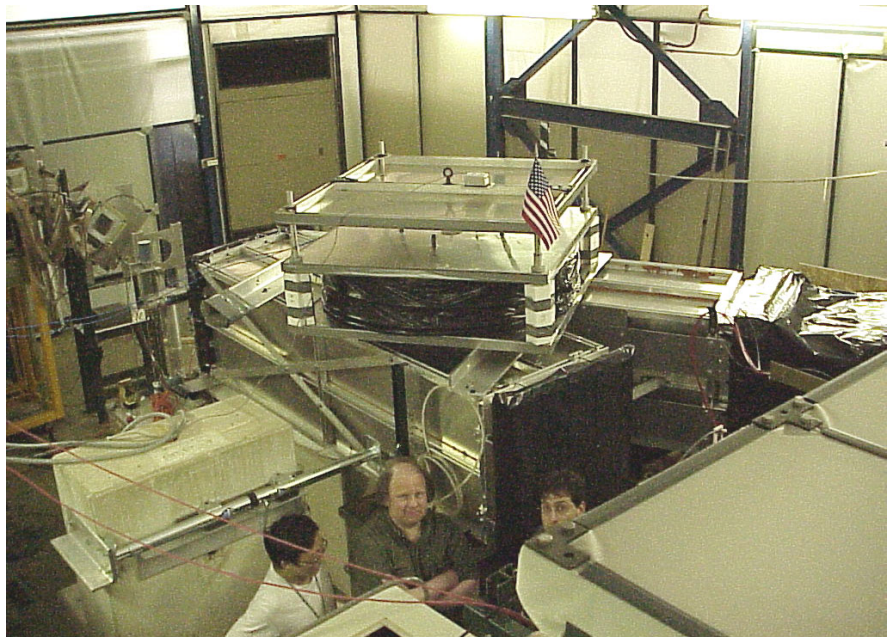




Channel receiving light responds at the expected level

C_4F_8O radiator test beam studies

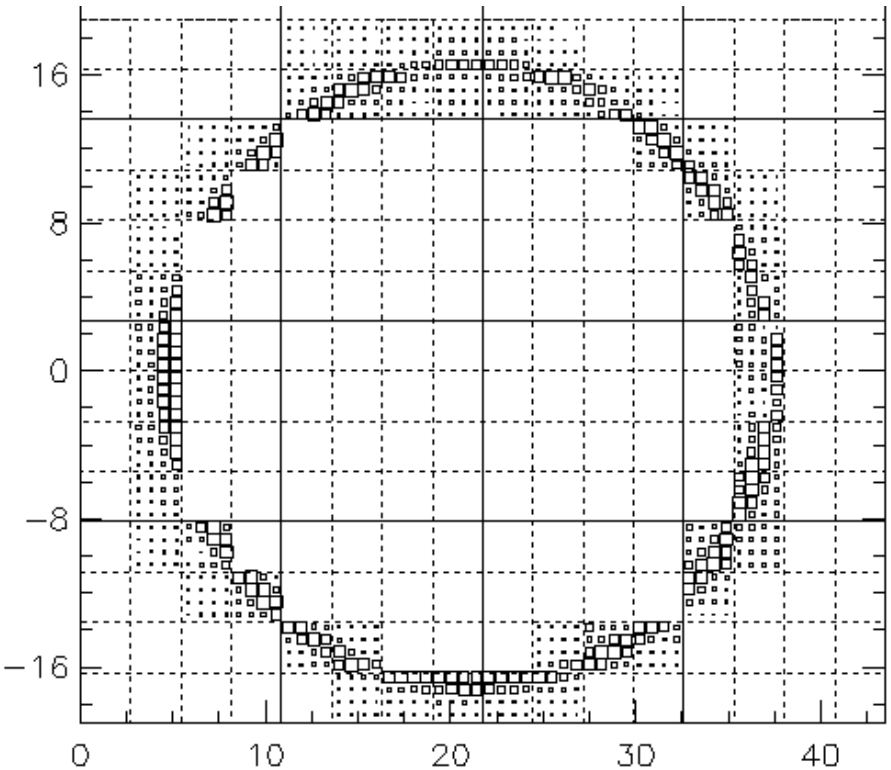




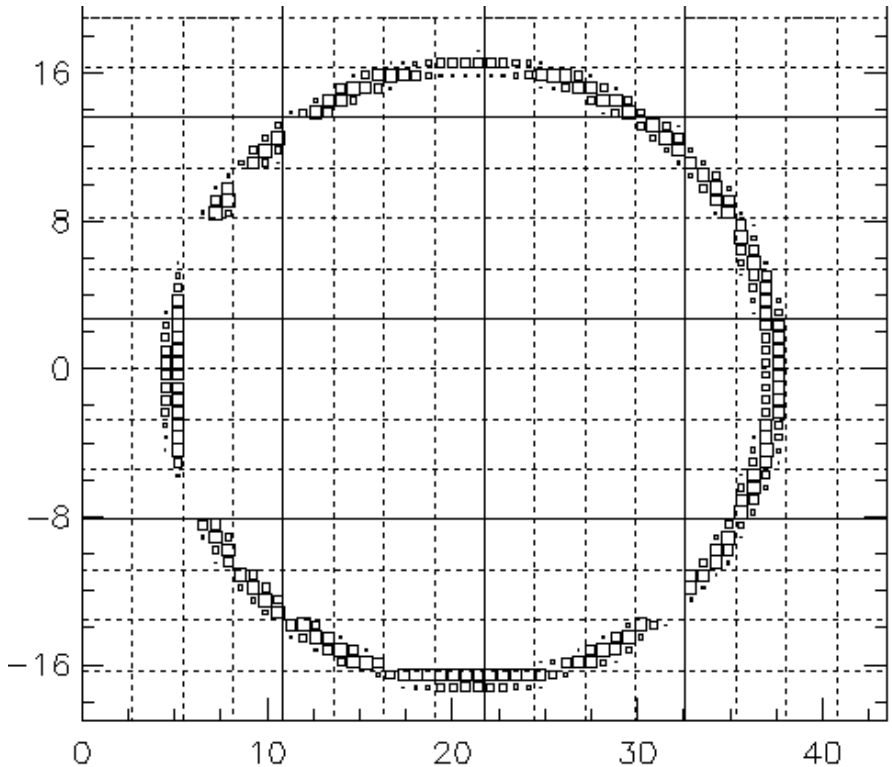
- All 52 MAPMTs deployed and read out with prototype front end electronics designed for our applications

The measured Cherenkov ring

data



MC



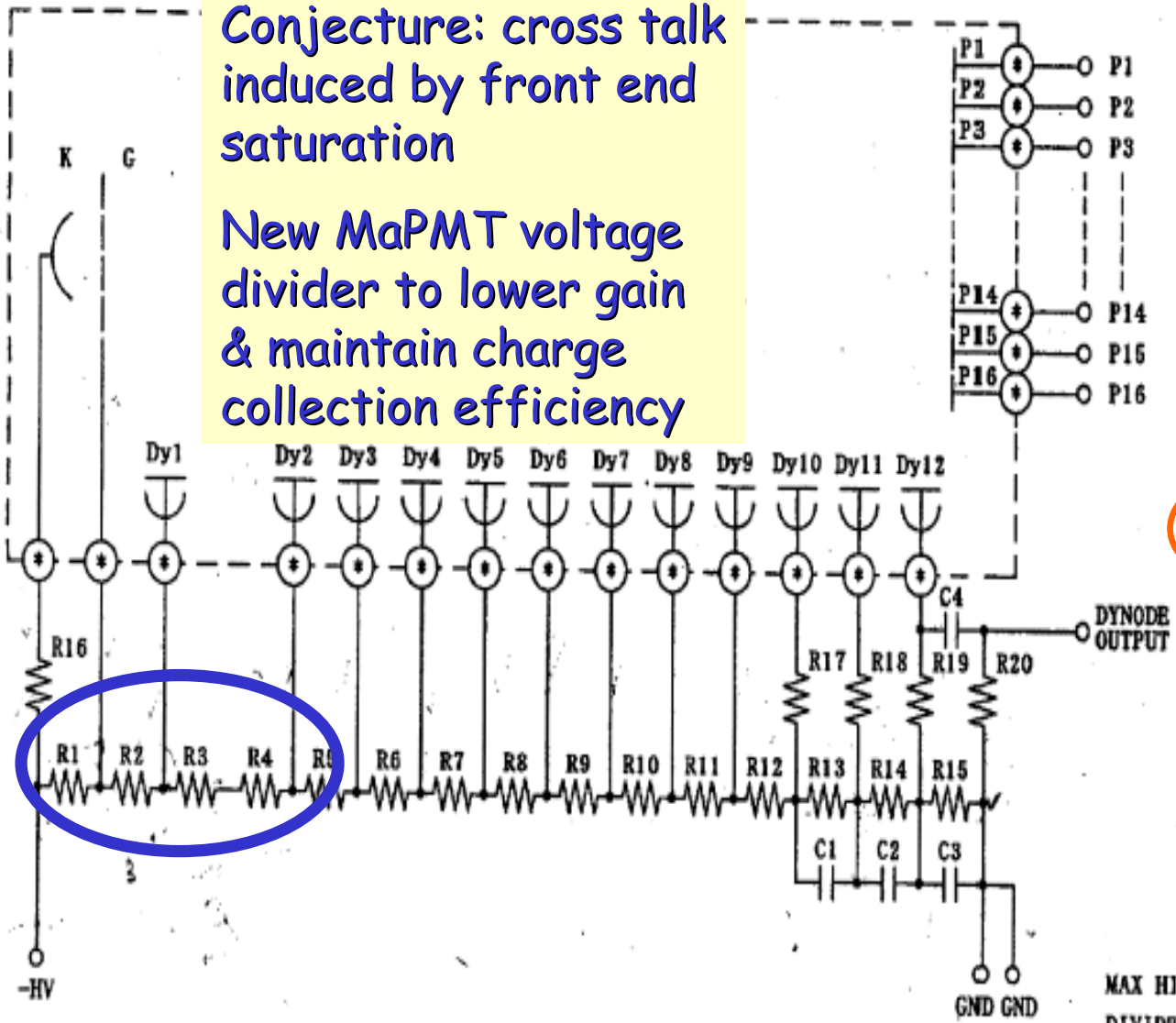
MC predictions in agreement with the data

More complete description in T. Skwarnicki's contribution

MaPMT gain tuning

Conjecture: cross talk induced by front end saturation

New MaPMT voltage divider to lower gain & maintain charge collection efficiency



R1,R4: 180kΩ

R2,R3: 540kΩ

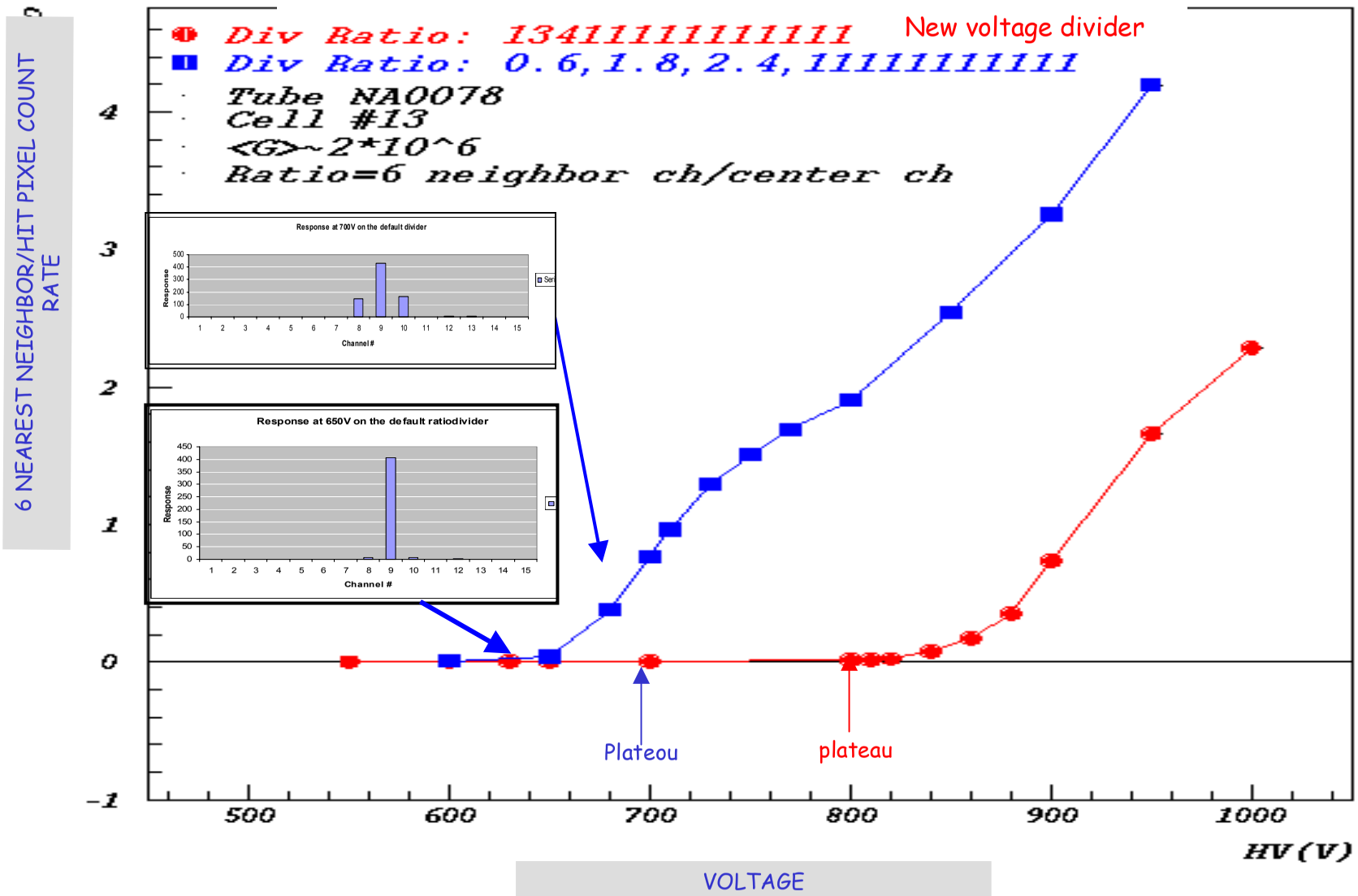
R5-R15: 180kΩ

1:3:4:1:1:1:1:1:1:1:1:1:1:1

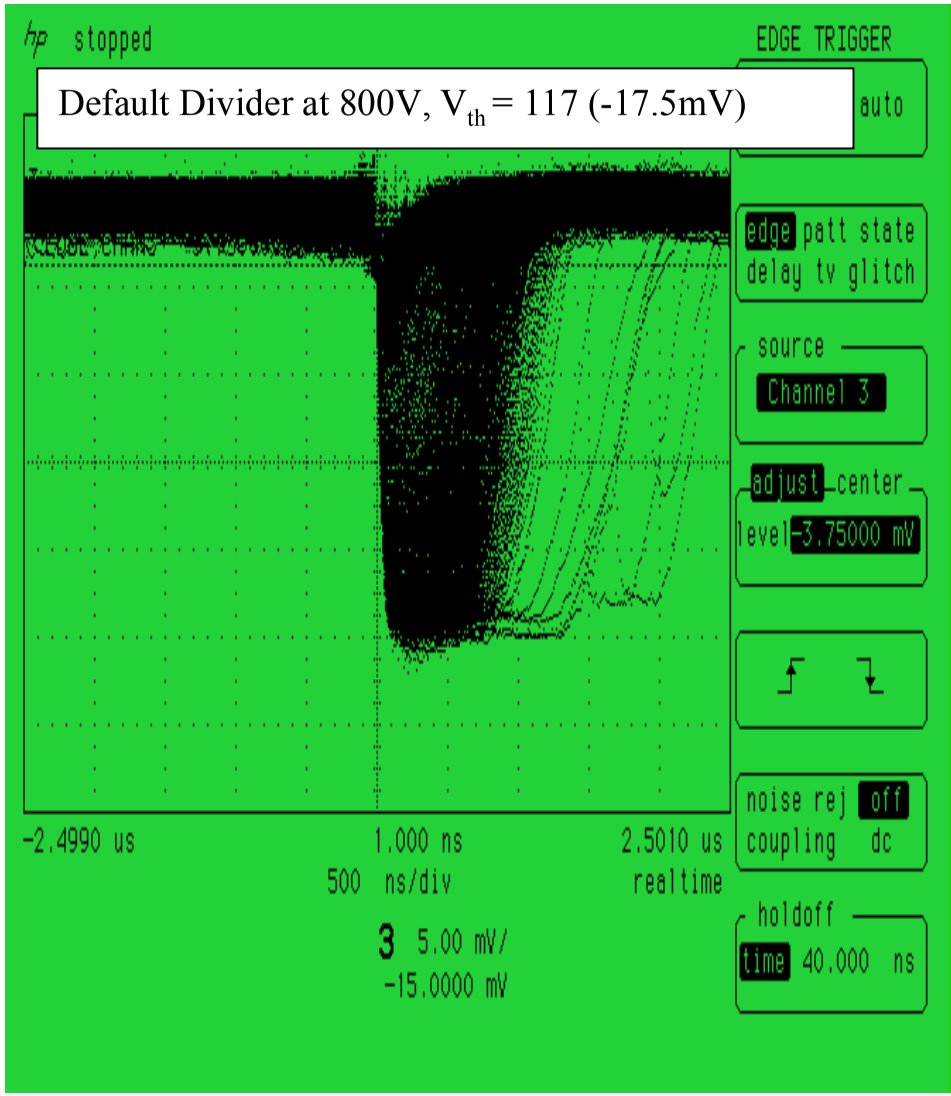
R1, R4: 110 kΩ (±5 %, 1/10 W)
R2, R3: 330 kΩ (±5 %, 1/10 W)
R5-R15: 180 kΩ (±5 %, 1/10 W)
R16: 1 MΩ (±5 %, 1/10 W)
R17-R19: 51 Ω (±5 %, 1/10 W)
R20: 10 kΩ (±5 %, 1/10 W)
C1-C4: 0.01 μF(200 V)

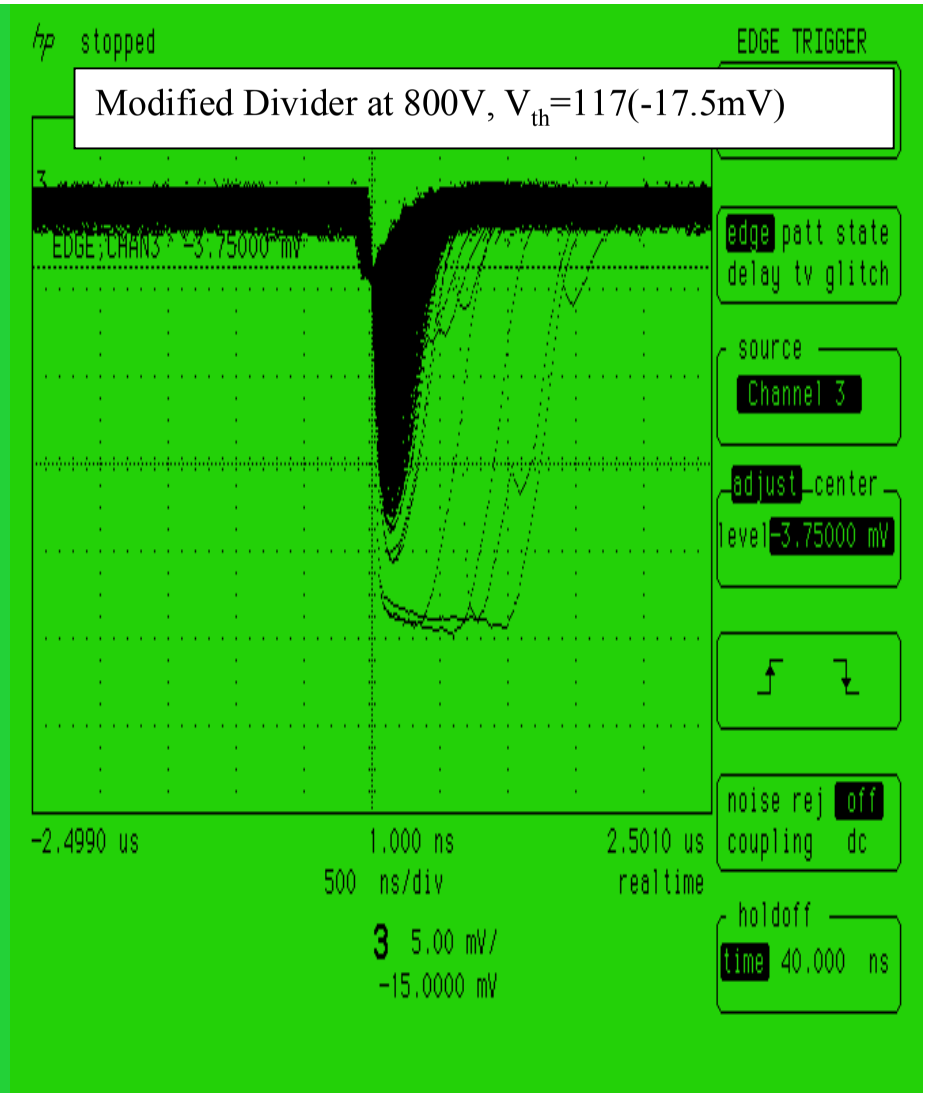
MAX HIGH VOLTAGE:-1000 V
DIVIDER CURRENT:350 μA(-HV=-1000 V)
DIVIDER RATIO 0.6:1.8:2.4:1:1:1:1:1:1:1:1:1:1:1

cross talk studies with 2 bias schemes



Analog outputs at different HVs

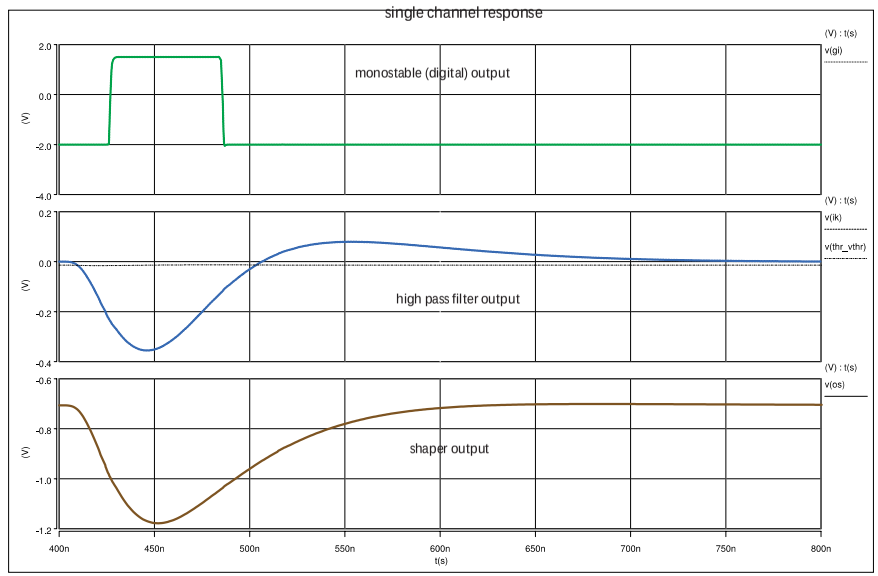




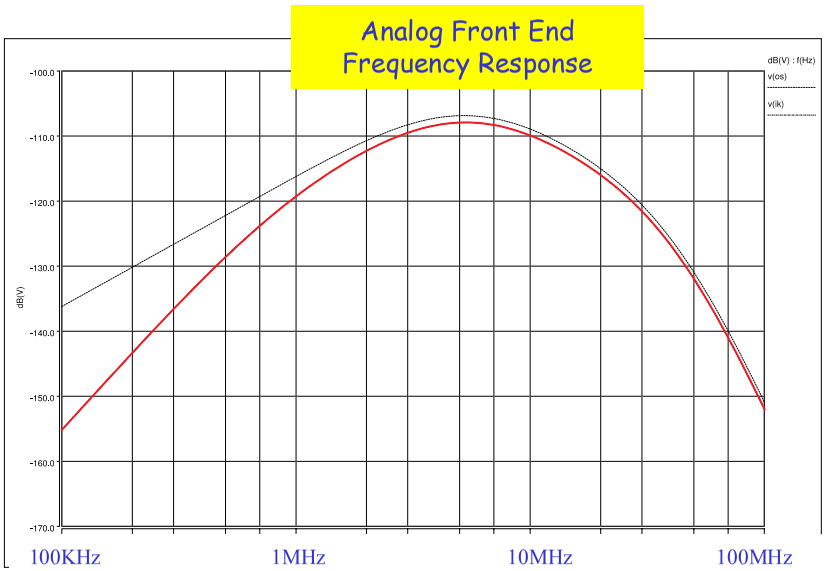
New ASICs under development

- MaPMT (optimized for dynamic range) and PMT (optimized for high input capacitance)
- Simulation studies:
  - Data rate capabilities
  - Filtering properties
  - Noise versus input capacitance

Time development of the signal

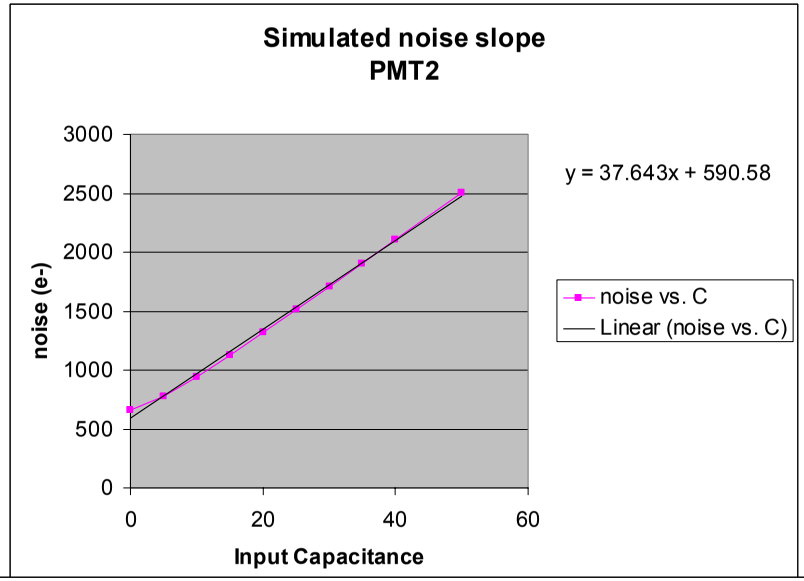


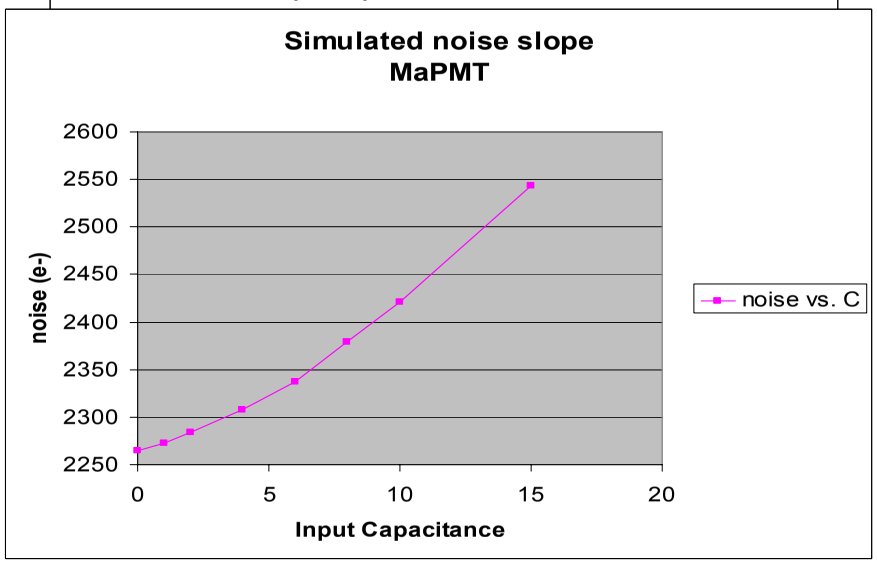
50 ns/division



100 ns/div

Predicted noise performance





- Equivalent noise charge versus input capacitance:
  - MaPMT has gain minimized to optimize dynamic range
    - ENC versus input capacitance non linear because there is a component from the shaper.
  - PMT optimized for high input capacitance
    - This ASIC has slightly higher power consumption to maintain the speed with the higher input capacitance expected [I am assuming C_{in} ~50 pF]

New devices will be tested in winter 2005

Concluding remarks

- The BTeV RICH photon detector electronics R&D effort has already produced several variations of a data driven driven low noise front end electronics, suitable for a variety of applications.
- We have gained experience with different packaging options [standard PCBs, mixed flex-rigid PCBs]
- Extensive tests in the laboratory + test beam runs have given us the operational experience that will lead to a successful system integration.