APD studies for tileHCAL

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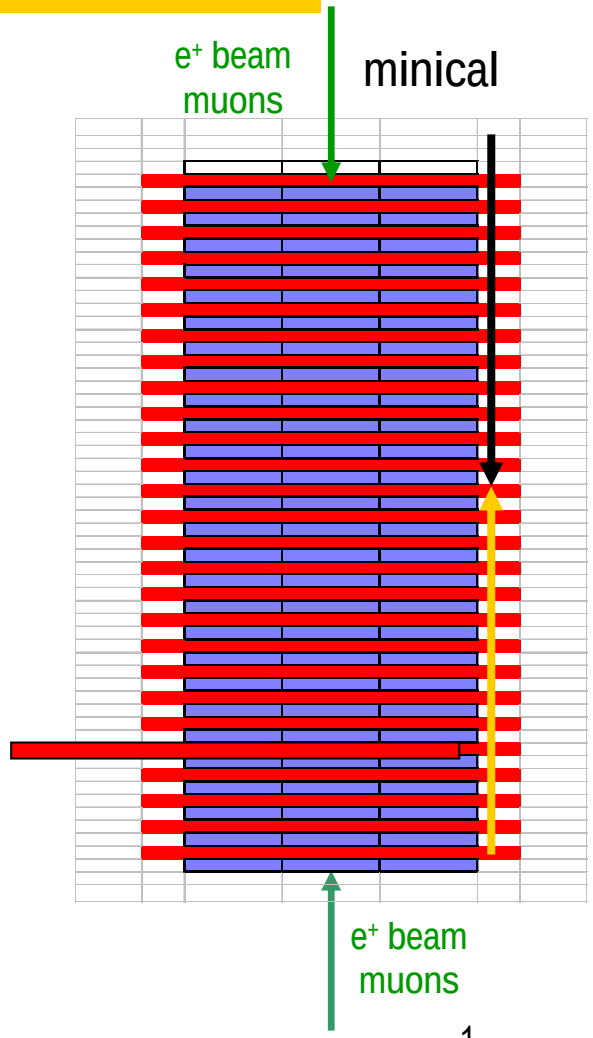
CALICE Calorimeter for FLC collaboration



- APDs and preamplifiers
- Energy scan with DESY beam in minical
- Conclusions

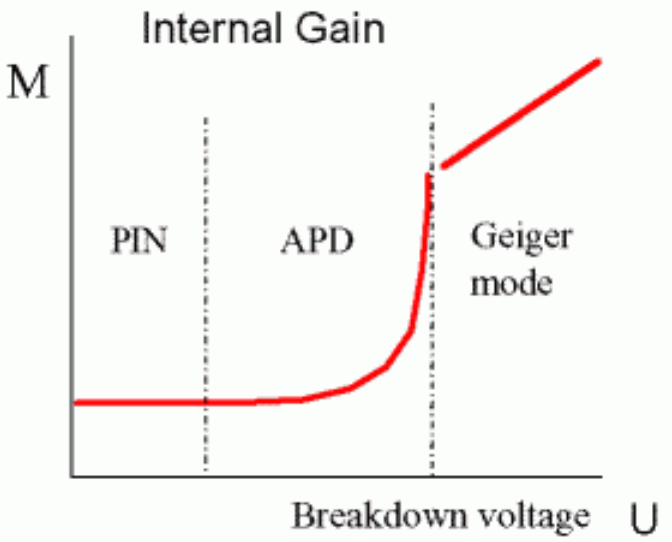
APDs

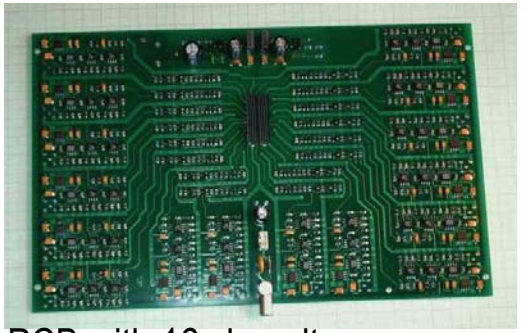
- APDs is considered as an alternative photodector for tileHCAL wrt SiPM

- Lower gain (~100-200), higher quantum ε~80%

→Low noise preamps and stable power supplies ($\Delta U/U \sim 10^{-4}$ for 1% gain stability)

- expensive
- We use Hamamatsu:
  - Single channel APDs S8664-55 (3x3 mm^2)
  - 32ch. matrix S8550 (with 1x1 mm^2 pads)
- 3 types of preamps available on PCB (now 9 channels):
  - Prague: voltage preamp – discrete components
  - LAL: charge preamp chip – 18 channels – 2 modifications
  - Minsk (Gilitski) charge preamplifier –1 integrated channel

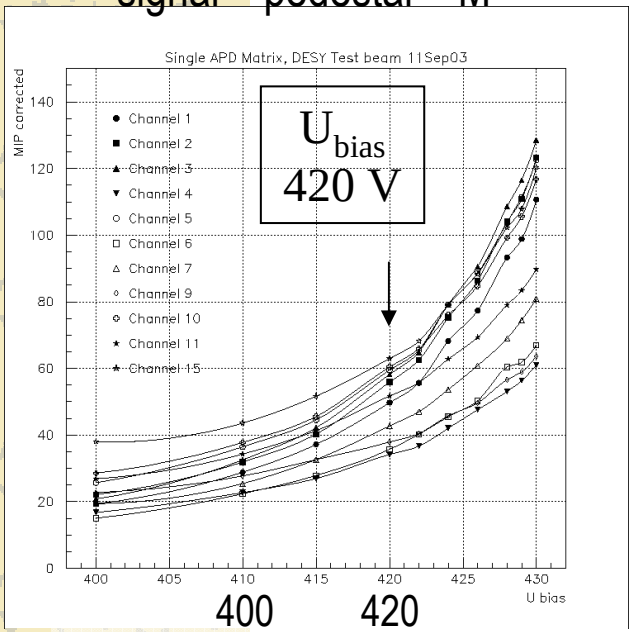




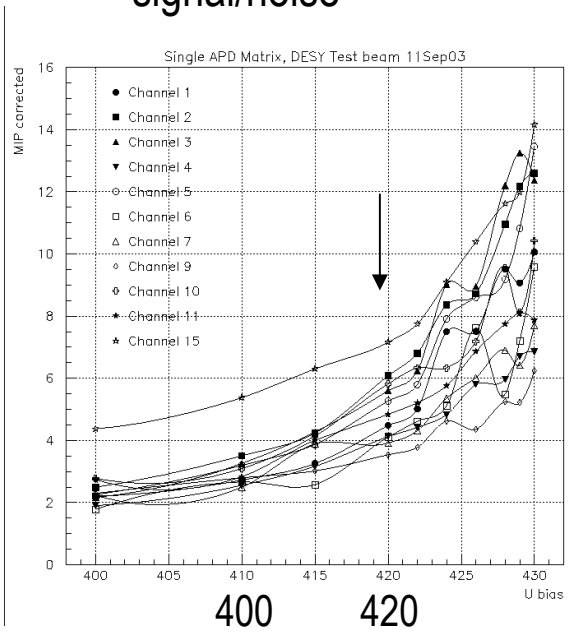
PCB with 16 ch. voltage preamp.

APD gain vs. U_{bias}

signal – pedestal ~ M



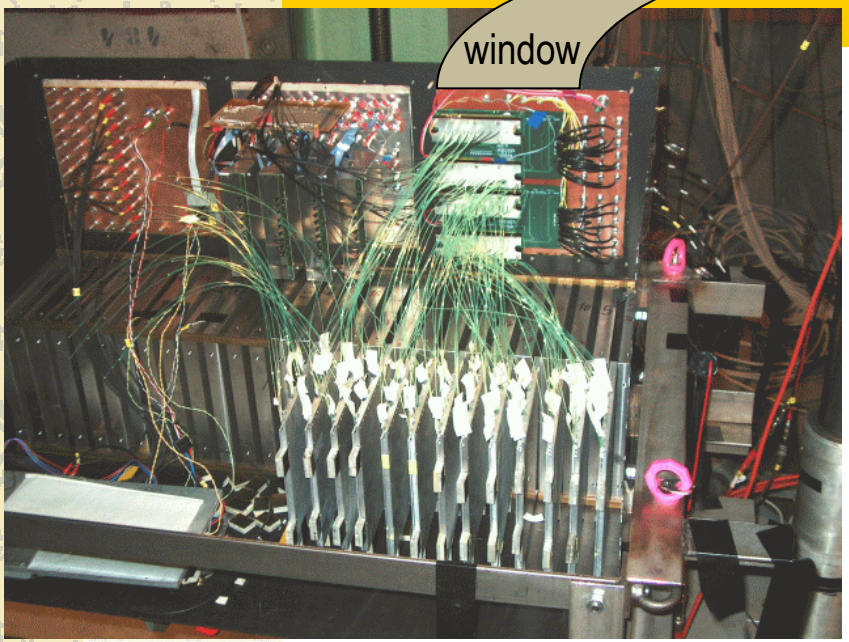
signal/noise

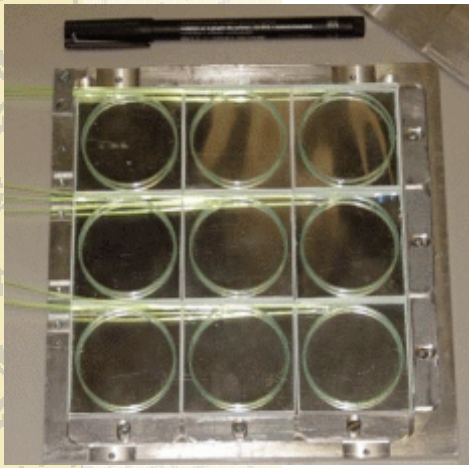


- Spread of APD gain ~ 50% at U_{bias} = 420 V for the voltage preamp.
- S/N ~ 4-6 for U_{bias} at 420 V.
- Working at lower U_{bias} -> more stable APD regime. Preamp gain can be adjusted.
- Shower signal in calorimeter must be attenuated. 10 bit ADCs have limited range.

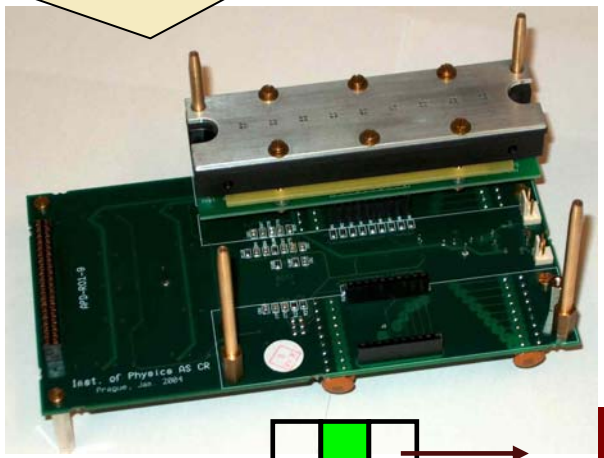
Beam tests

13 planes
32 APD channels



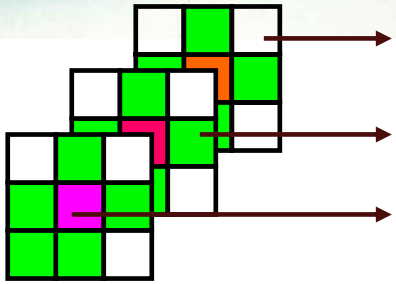


Cassette – 1 plane
- 9 tiles 5x5x0.5 cm^3 (Bicron BC408, Protvino)
- WLS Kuraray Y11-200)
- 1-loop fibre in groove not glued
- Tile covered by 3M reflector



mask

PCB with
APDs + preamps



Not read

3 tiles/APD

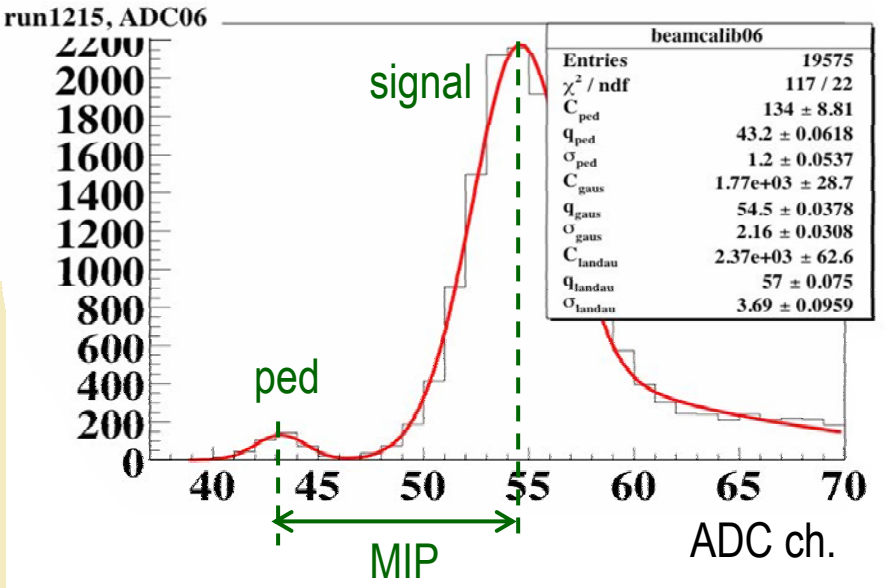
1 tile/APD

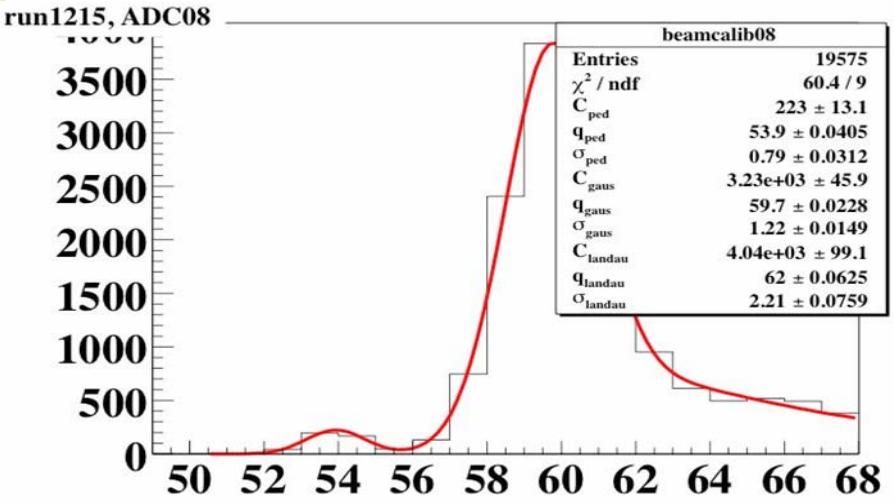
- For comparison with PM & SiPM – 13 layers read individually (Minsk preamp)
- No. of channels limited – only 33 APDs available!
- LAL preamp chip used in mode with 3 tiles read by 1 APD (32 channels)

MIP calibration of APDs

- 3 GeV e^+ beam shot through cassettes pulled off absorbers
- Fit in all channels:
  - Gaussian for pedestal
  - Gaussian & Landau distribution (sampling fluctuations) for positron
- MIP = (positron – pedestal) peaks

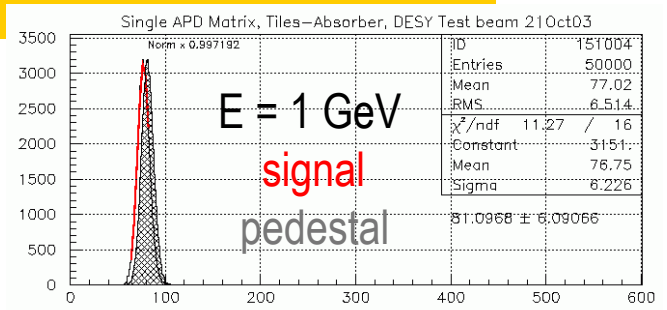
  renormalization constant for each channel
- Energy(in MIPs) = Σ over channels in MIPs
- Pedestal determination brings uncertainty by + 1 MIP channel into E_Σ (corrected)

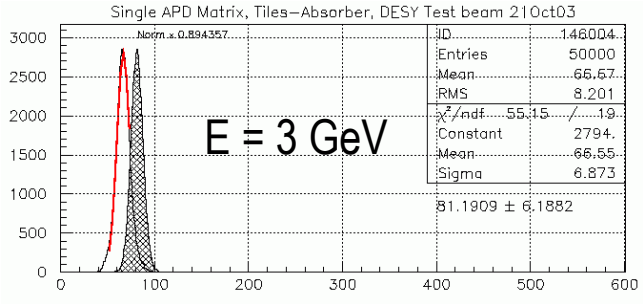


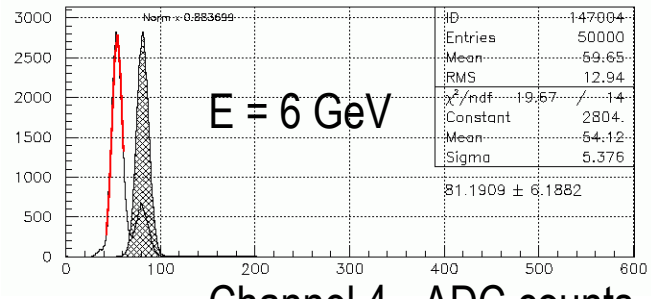


Cross talk between channels

- Minical in beam
  → change of pedestal for channels not optically connected to scintillator – done with (LAL preamp)
- negative cross talk ≈ -1 %
- xtalk(ch *k*) = $(S\text{-}ped)_{ch\ k} / \sum_{central} (S\text{-}ped)_{ch\ i}$
- Cross talk < 0.5% for Minsk preamp in calibration runs

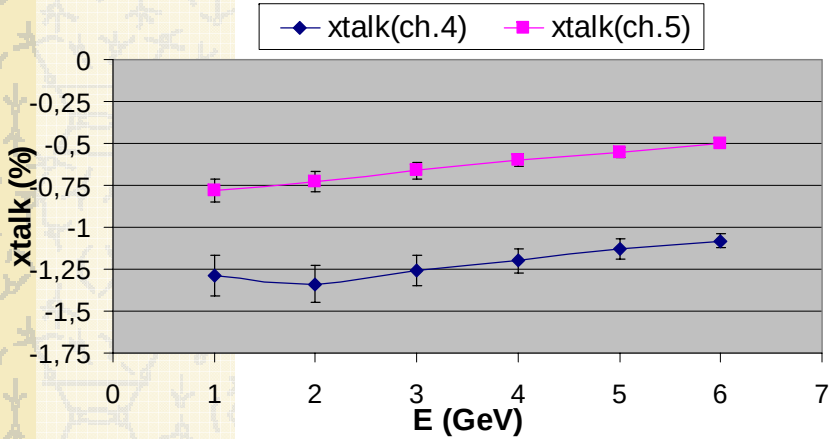






Channel 4 - ADC counts

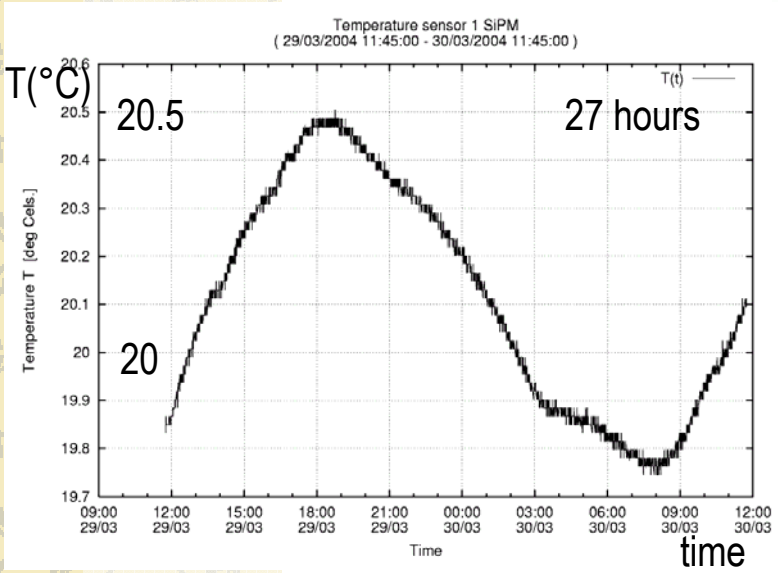
Cross talk - LAL preamp

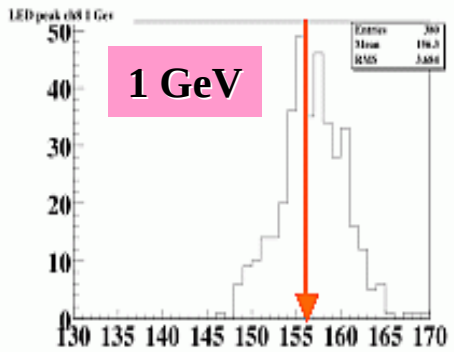


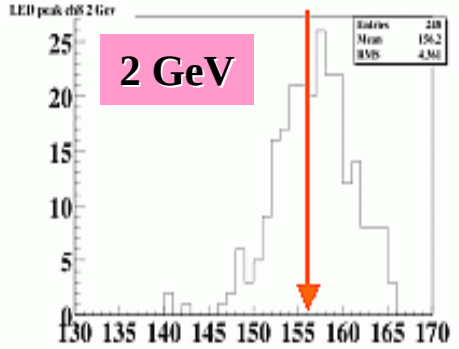
LED Monitoring of APD's

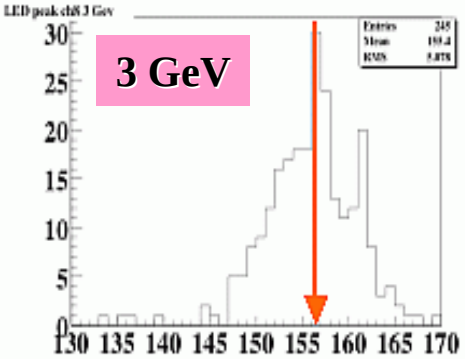
- LED light – 10 Hz to all APDs
- APDs stable within ~ 1% over period 1 – 2 hours, typical run period
- Temperature variations in minical:

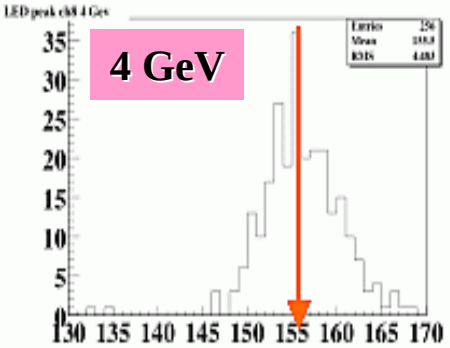
  < 1.4° C over period of 24 hours

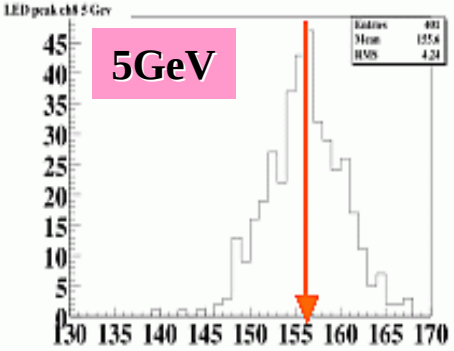


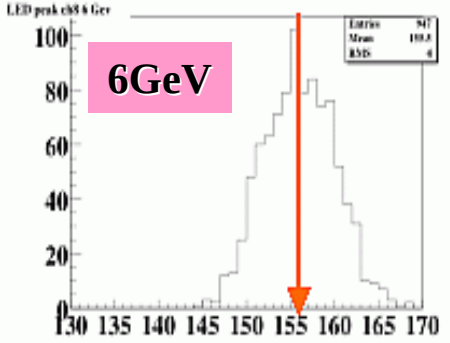




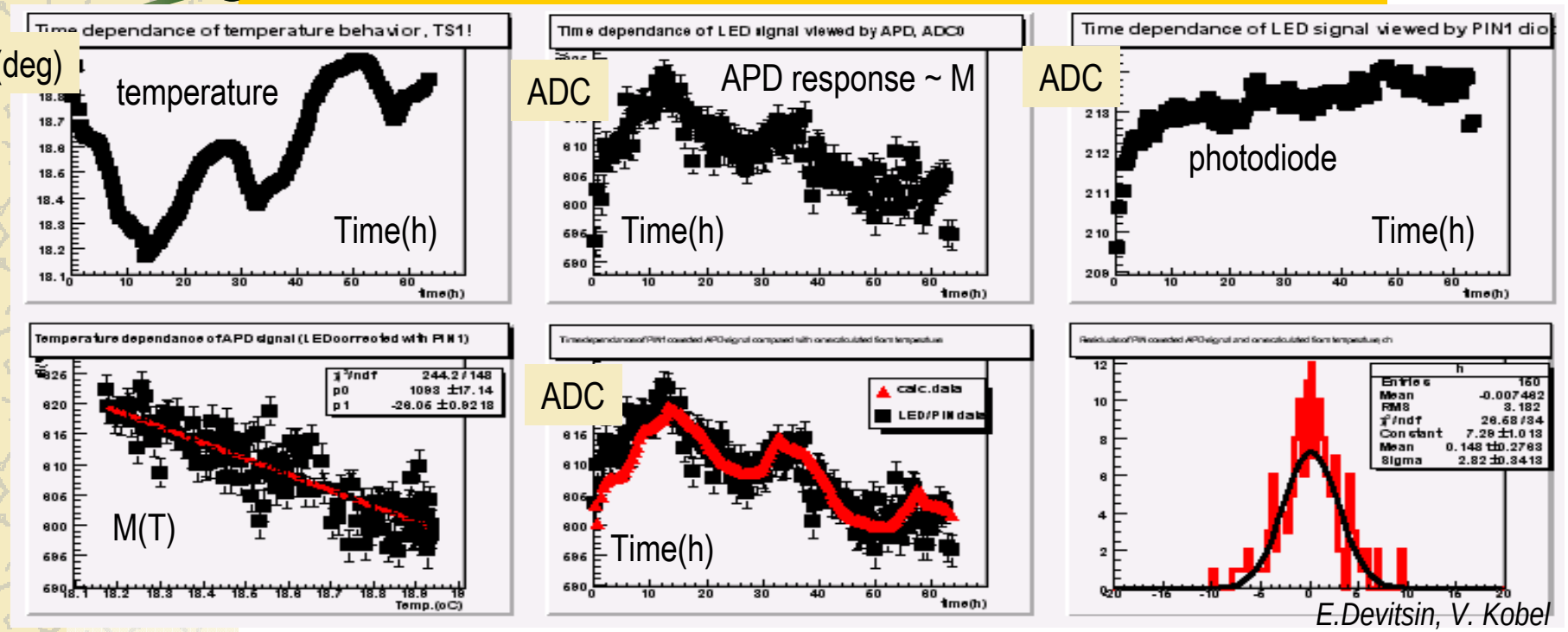








Temperature monitoring & correction



APD temperature monitored by the slow control system

- APD response to LED signal recorded (corrected to a nominal LED signal)
- Linear: M(T) ~ P1 + P2 * T

→ 1/M dM/dT ~ -2.4%/deg

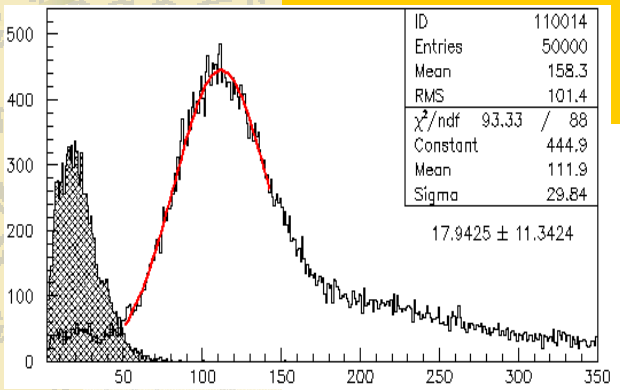
depends on gain M (each APD own curve?)

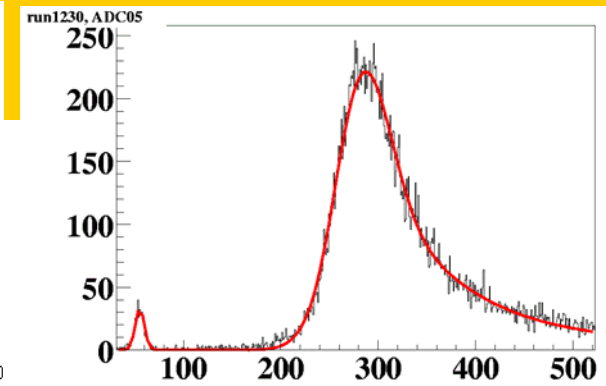
- Good reproducibility of monitoring obtained

Next steps:

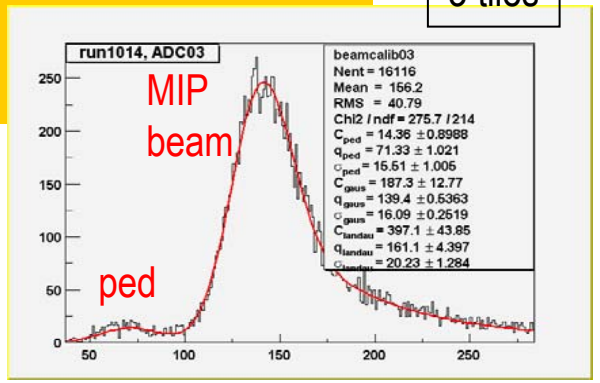
- correction function for all APDs
- LED/PD corrections on single event level
- Can LED/PD work without temperature measurements as for MAPMs and SiPMs?

Preamplifiers - comparison





3 tiles

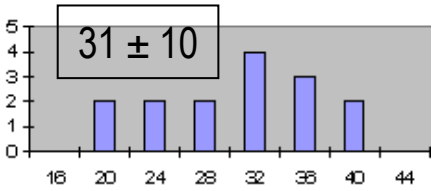


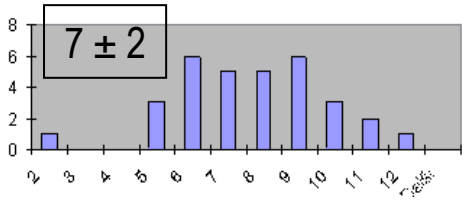
Voltage sensitive Prague
1ch. discreate + shaper
Gate: 120 ns
Noise (S/N): 6
MIP res.(M /σ_M): 3

Charge sensitive Minsk
1ch. integrated + shaper
500 ns
31
7

LAL ECAL modified chip
18 ch. + shaper + track&hold
780 ns
7
4

- Minsk preamp wins
- Noise (coherent) investigated
- Beam tests continue
- Preamps need modifications



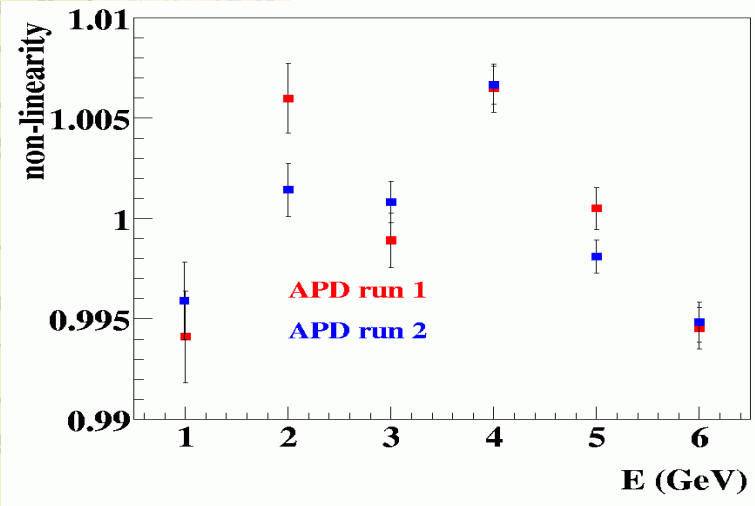


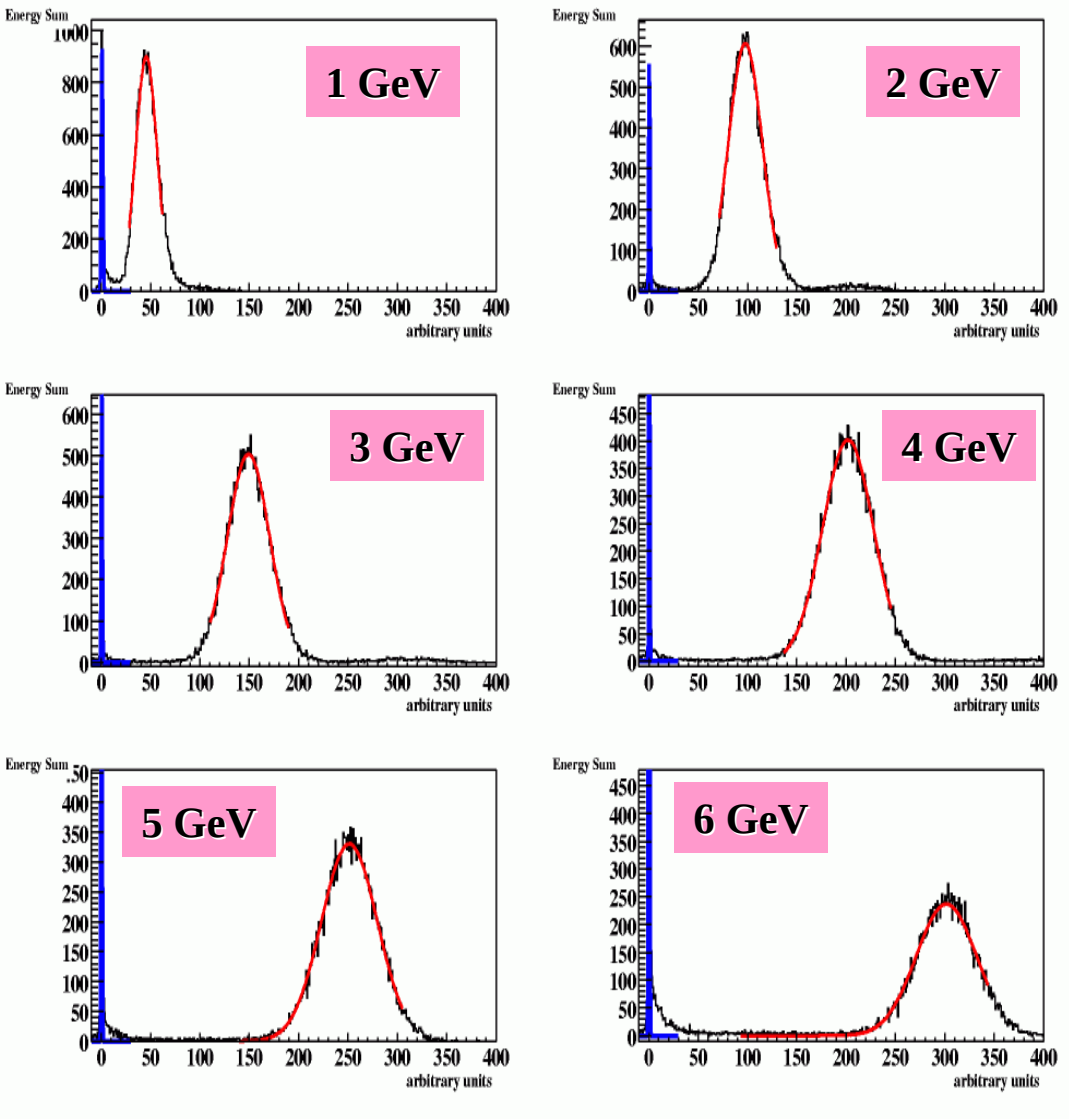
S/N for APD channels, e^+ 3 GeV calibration run, 3 tiles

higher S/N due to:
-U_{bias}~400V
-higher preamp gain

Energy sums

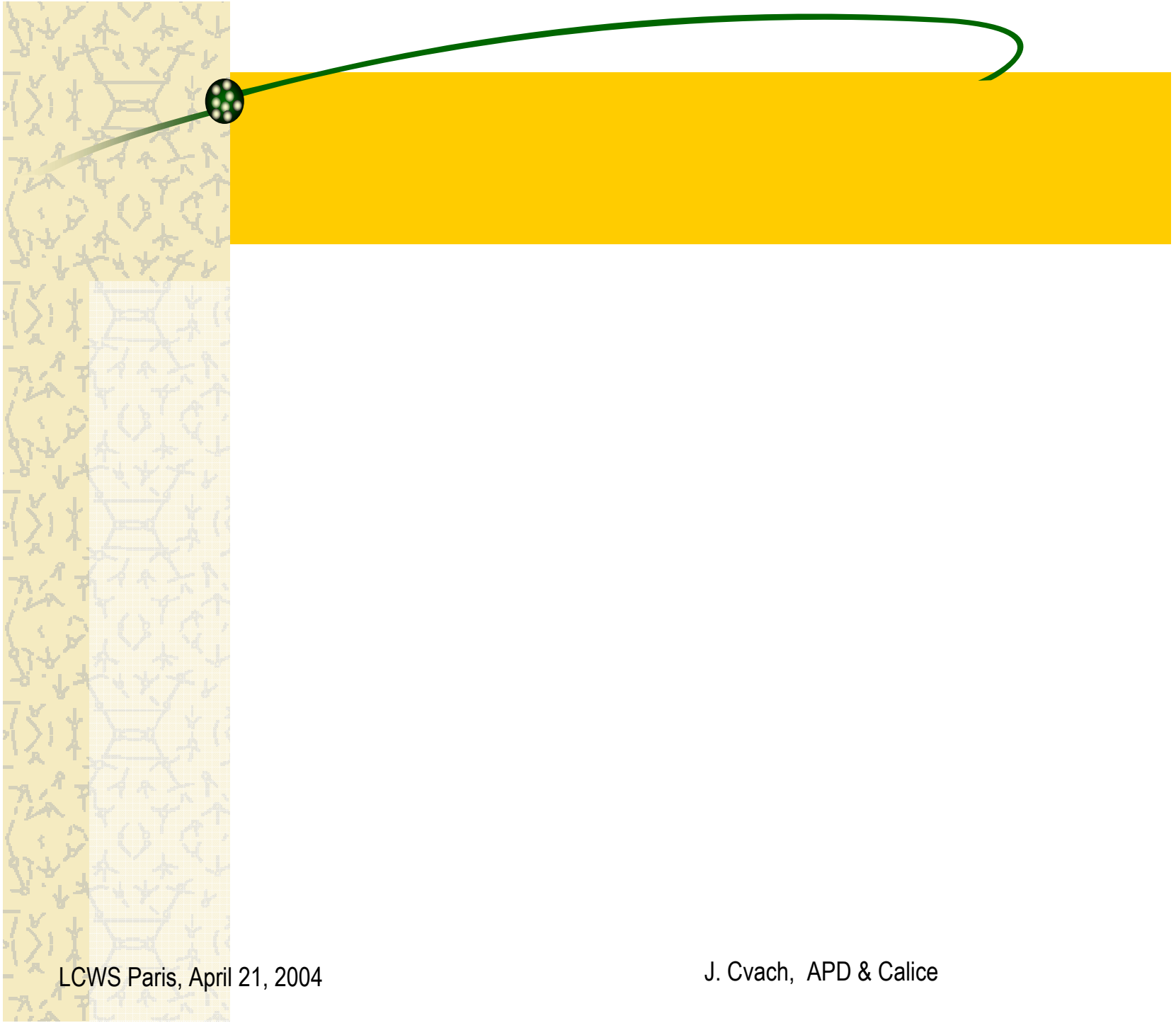
- Σ energy corrected of 93 tiles for beam energies of 1-6 GeV
- Very good Gaussian shape
- Data show good linearity in E within 0.5%
- Agreement between two energy runs better then 0.2%
- The proper scale is investigated





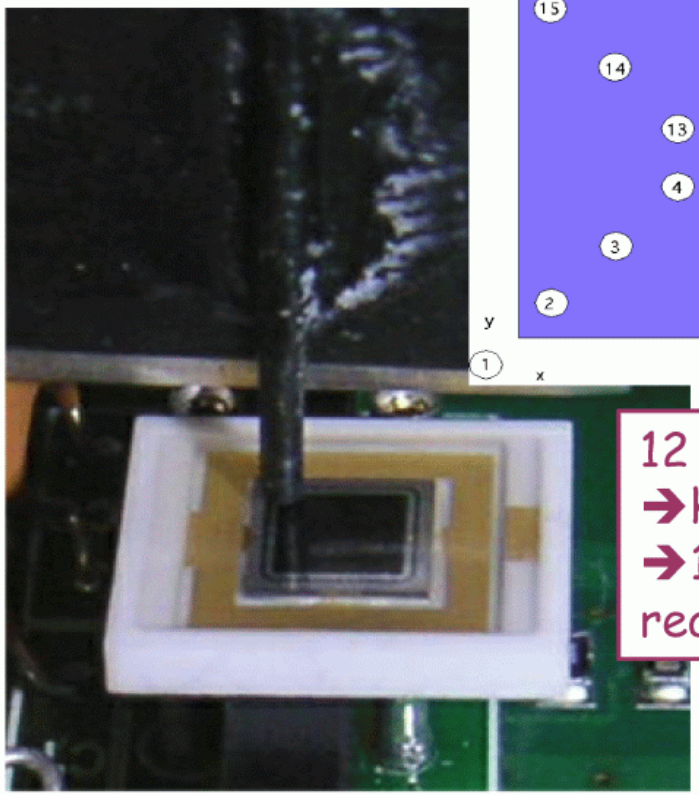
Conclusions

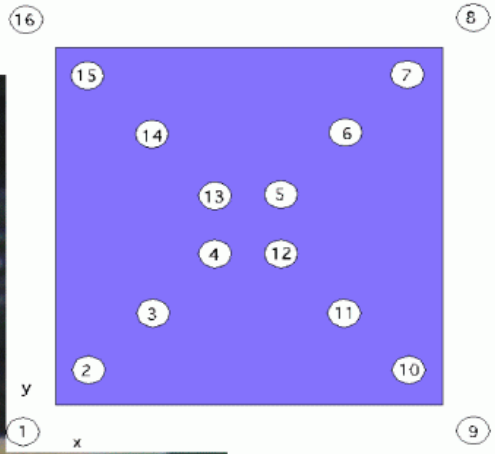
- Tests with two preampliers finished – data analysis is in progress
  → first results reported
  results look good, good linearity obtained, good time stability
- The sophisticated LED calibration system is available
  → we understand temperature monitoring, can correct for T variation
- Beam tests with other preamplifiers will follow
- APD photodectors are competitive readout for analog HCAL
  we expect to reach performance comparable to SiPM



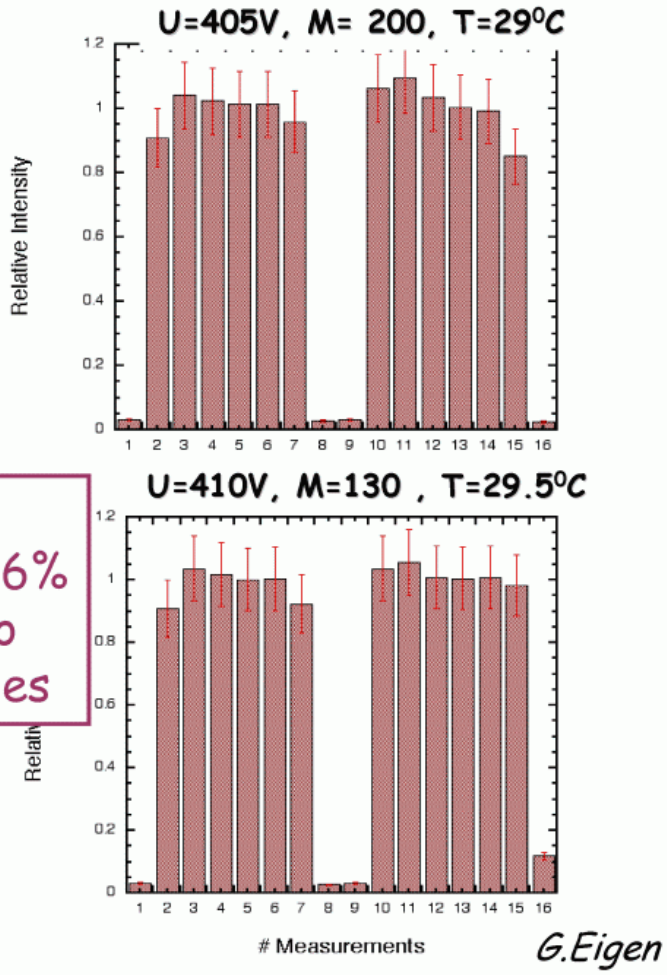
Backup Slides

Photocathode homogeneity





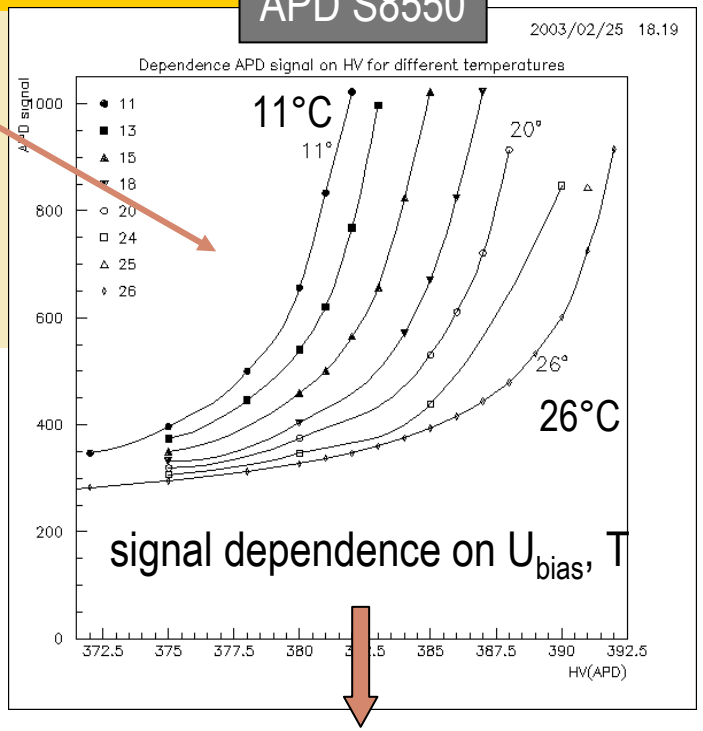
12 APD tested
➔homogeneity 6%
➔1 APD used to read out 3-4 tiles

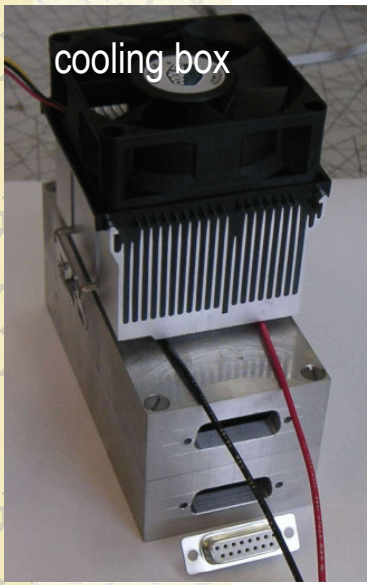


Thermobox for APD *T* dependence

- Significant APD sensitivity to the temperature
- Precise temperature monitoring
- Knowledge of APD gain dependence on T
- Dedicated equipment needed – Peltier cell

APD S8550





- stability 0.2 deg, resolution 0.1deg
- actual & preset temperature display
- status indicated by LEDs

construction in progress

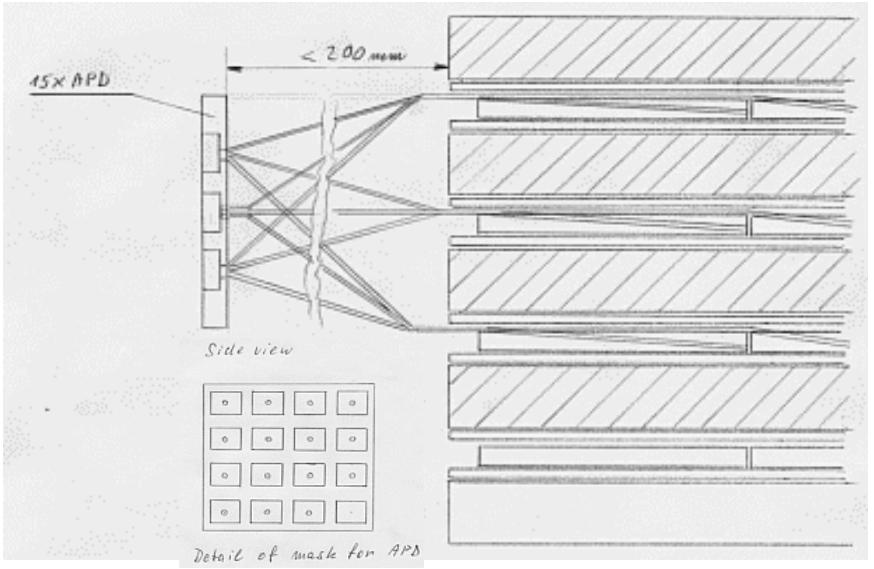
at high gains:
15%/V, 11%/K

APDs & physics prototype

Material for 3 planes of physics prototype:

- tile size - 60 x 60mm^2
  - 225 tiles/plane (x3) = 675 tiles
  - 225 APD ~30 k€ (Hamamatsu)
  - WLS & calibration fibres – 550m
- tile size 120 x 120mm^2
  - 64 tiles/plane (x3) = 192 tiles
  - 64 APD
  - WLS & calibration fibres – 160m

- With the current APD price → 3 planes of ppt can be considered only
- It is desirable to test an alternative photodector wrt SiPMs



In case cheaper APDs will be found → solution with 1APD/tile as for SiPMs