TileHCAL- fibre readout by APD

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- APDs and preamplifiers
- Energy scan with DESY beam
 - Energy resolution
 - Cross talk
- 🕹 Conclusions

Short reminder

- Measurements of characteristics of 32ch. matrix S8550 and single channel 3x3 mm² S8664-55 APDs summarized in Amsterdam by S. Němeček
 - Gain and excess noise factor calculated
 - Gain dependence 1/G*dG/dT = ~12%
 - Gain dependence 1/G*dG/dU = ~15% at max G
 - PS with $\Delta U/U = 10^{-4} \rightarrow 1\%$ gain stability
- Single channel APDs S8664-55 (3x3 mm²) better in all characteristics than 32ch. matrix S8550
- New preamp chips (25 pieces) were delivered (beginning of July) based on LAL Orsay design for ECAL – we made PCB + masks
- ★ 2 types of preamps:
 - Prague: voltage preamp discrete components -16ch
 - LAL: charge preamp chip –18 channels



APD gain stable at 1% level: $\Delta U/\Delta T \simeq -0.65 V/^{\circ}C (G \sim 200)$

APD tests at DESY e beam

- Calibration run tiles not in the absorber (each APD connected to 3 tiles = 1 cell)
- same U_{bias} for all APDs →
 different gain of APDs (optical contact between fibres and APDs) leads to the spread of the signal
 E_{beam} = 3 GeV, U_{bias} = 400 440 V
- Calibration constants used for all E_{beam}

80

Calibration for Prague preamp, Ubias = 420 V





Prague preamp, mask with 45 fibres (15 ch.), beam enters from the right to the tile row

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We decided to use $U_{bias} = 420 \text{ V}$ for the Prague preamp.

>S/N ~ 4-5 reasonably large for mip at 420 V.

We can work at lower U_{bias} (more stable APD regime). Preamp gain can be increased.
★But in the shower signal must be attenuated! We are limited by ADC range.

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E measurements in minical – LAL preamp



5.5 cm

Beam positioned in the tile centre with accuracy better than ± 1 cm

 \succ E_{beam} = 1 − 6 GeV in 1 GeV steps, T = 25°C, U_{bias} = 415 V

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Shower development with APDs

➢ ADC counts for cells 1-4 at E_{beam} = 1–6 GeV, signal in cells 1-3 reduced by 10 dB
 ➢ Cell 4 contributes to signal by ≥ 4% for E_{beam} ≥ 4GeV



Energy sums for APD readout



ADC counts

- Cells 1-4 calibrated by the cell signal taken with 3 GeV w/o absorber plates: corrections ≤ 10%
- ➢ Contribution from cell 4 at E_{beam}
 ≤ 3 GeV is negative (~ 1%) ->
 cross talk
- LED calibration was tested but was not available for cells 1-4
- Signal fitted by Gaussian and used for energy resolution

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Energy resolution with APDs



Good linearity, small systematic deviation in the slope (beam not in the tile centre?)

No estimate of systematic error yet

Energy resolution comparison (see Erika):			
it values for	PM	APD	MC
P ₁	0.1 ± 0.2	0.5	0.4 ± 0.2
P ₂ (%)	21.0 ± 0.4	24.4	17.1± 0.1
SiPM values similar to PM values			

- reasons for worse resolution:
 - noise of APD
 - lower tile light yield (estimate: 17 ph.e./tile)
 - tile alignment (alignment with beam)
 - calibration

Cross talk between channels - LAL preamp

- ➢ In the energy scan → cells 1-4 connected to preamp channels 3->0
- Remaining channels show negative cross talk ≈ -1 %



Cross talk at U_{bias} = 415 V







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Cross talk between channels - Prague preamp

- Calibration measurements with APD S8664-55 (3x3 mm²)
- light collected from 3 tiles in 3 GeV ebeam (~mip)
- All preamp channels but one (channel
 0) connected to APDs → cross talk
- <mark>と Ubias =</mark> 400 430 V
- Cross talk = (S-ped)_{ch 0} /(S-ped)_{ch 1}
- cross talk < 1% for all Ubias</p>
- Cross talk between preamp channels ≤ 1% (true for Prague and LAL preamps)



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50

100

150

200

300

200 100

0

400

15.7633 ± 11.1243

300

350

250

ADC counts

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Cross talk between pixels – S8550 (Prague preamp)

Pixels with light

Pixel without light



Conclusions

- We have 4 preamp types for APDs they were not optimized for conditions of the calorimeter
- The sophisticated LED calibration system was tuned with PMs -> go for tests with APDs in minical!
- We have PS with ΔU/U = 10⁻⁴. APDs will be sorted into groups with the same gain and connected to the same U_{bias}
- Temperature must be recorded during measurements (we prepare in Prague a temperature stabilized chamber and will measure the APD gain dependence on temperature) – will be LED calibration sufficient?
- First measurement of energy resolution with APDs in minical show good linearity but worse resolution in comparison with PM and SiPM. Forthcoming beam tests will improve it!