Forward Endcap

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RUHR UNIVERSITÄT BOCHUM RUB

Topics

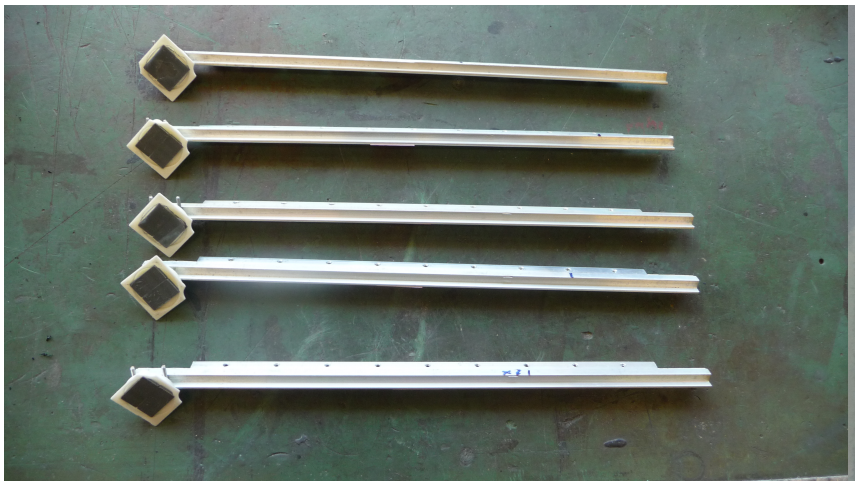
- Glueonic Excitations:
  - Usage of primer
  - Roughen of surface
  - Vacuumizing
  - Capusle design
  - 1:2 problem
  - Comparison of barrel and forward endcap glueing
- APD preamps
- APD screening results

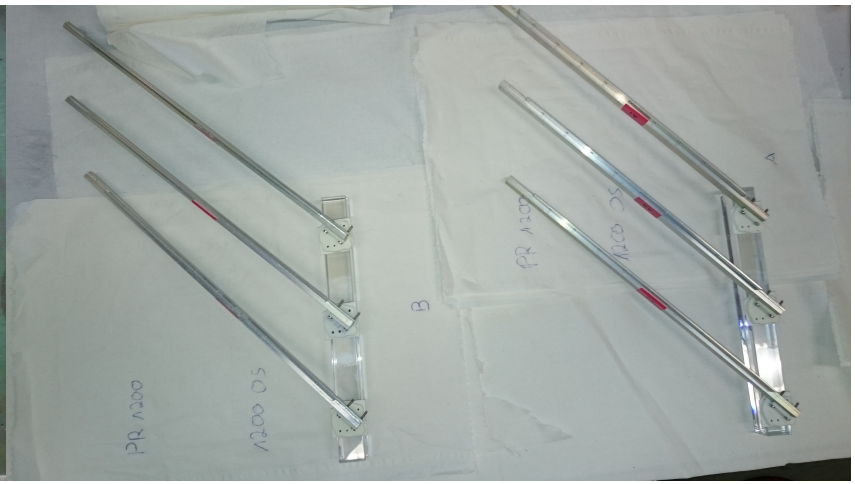
Glueing: Primer

- Observation: Many broken photodetector-crystal couplings
- Couplings brake after (many) cold-warm cycles
- $\Rightarrow$ Review of glueing technique
- Use of special primer fluids by the glue manufacturer
  - Primer PR-1200 RTV
  - Primer 1200 OS
    (not recommended, transparency compromized)
  - Primers improve adhesion of moisture reactive silicons
    to non-porous substrates

Glueing: Primer

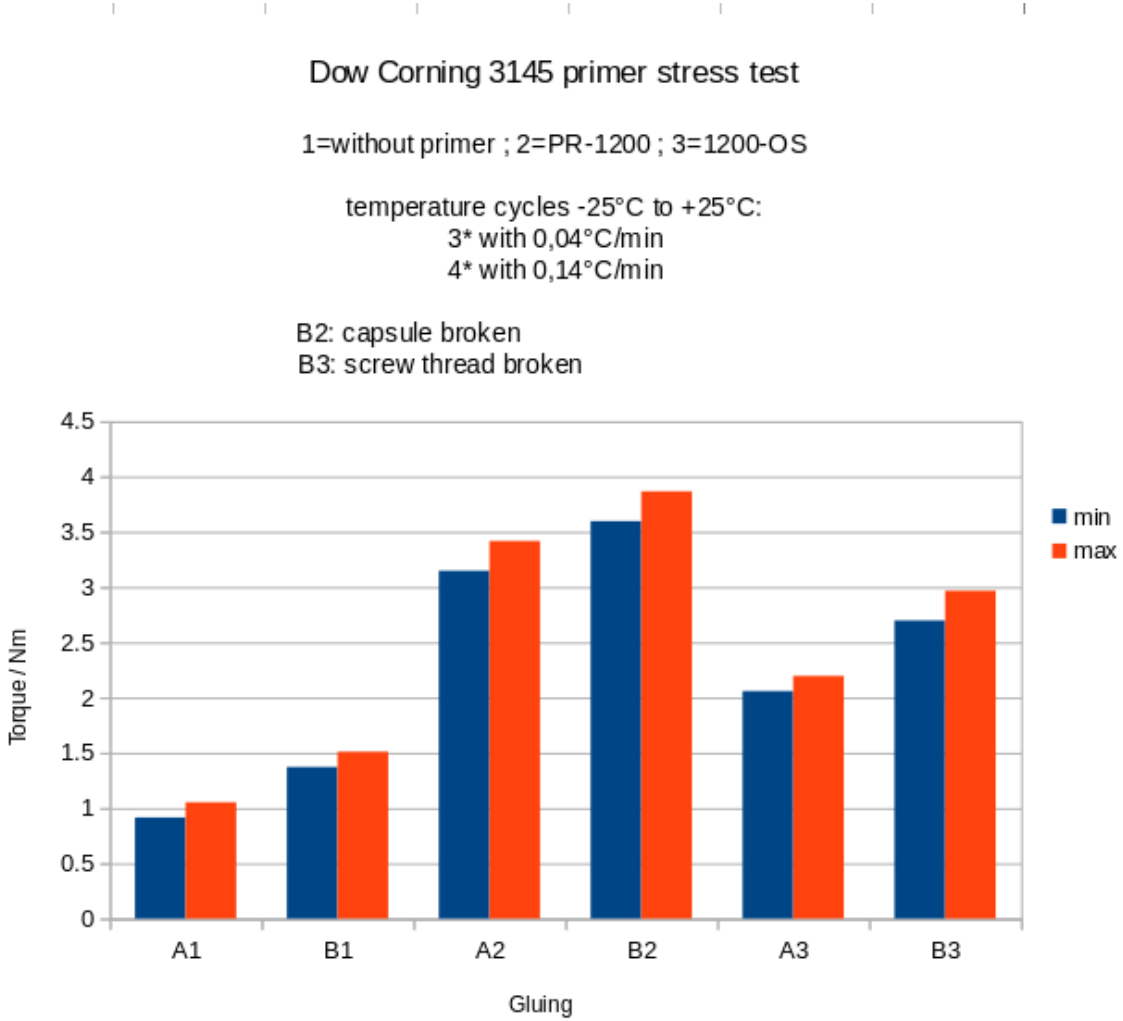
- Test setup: Capsules with plastic APD dummies and lever arm
- Necessary force/torque to break coupling?
- Setup used for w/ vs w/o primer
  and w/ vs. w/o vacuumizing comparison





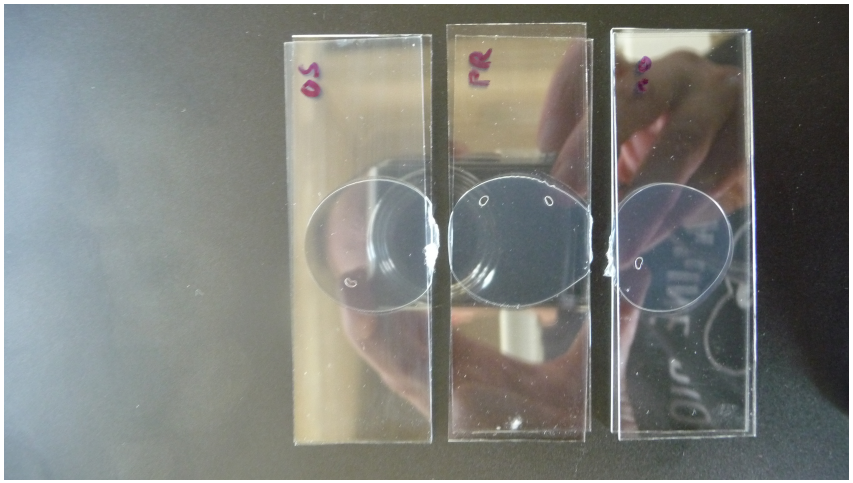
Glueing: Primer

- Improvement of coupling by use of primer:
  Three times the torque necessary to break the coupling!



Glueing: Primer

- Applied as indicated in data sheet (prevent overdose!):
  no visual difference
- Test pieces (glass plates glued together) prepared
  and given to Giessen for
  - Quantitative comparison of couplings
    w/ and w/o primer(s)
  - Check for radiation hardness of primer supported coupling
  - Use of primer on APDs as well?
    Weak link has always been crystal coupling...

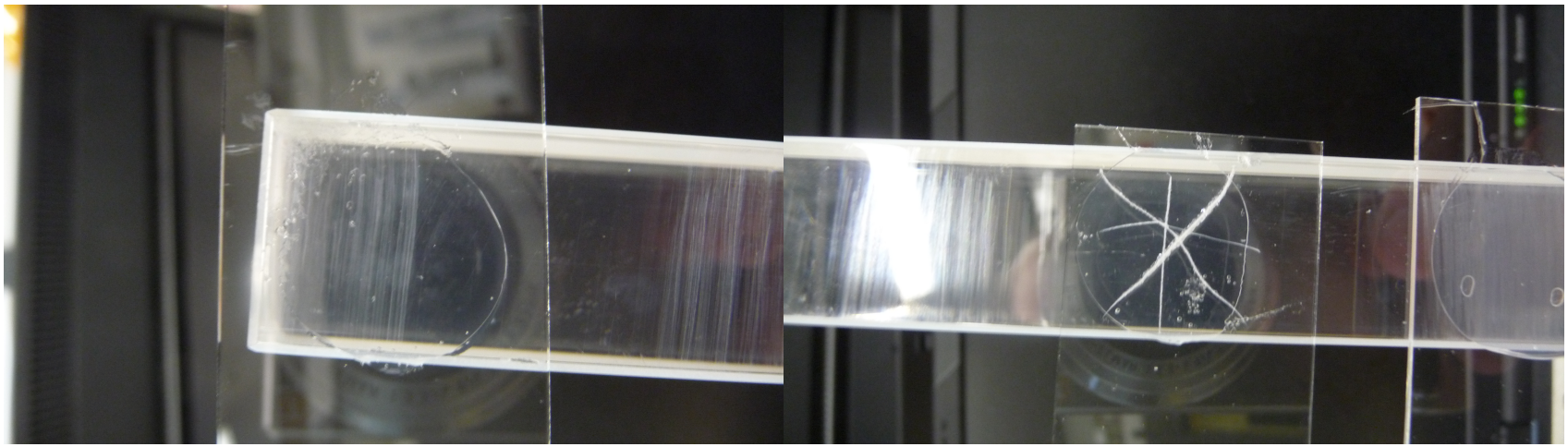


Glueing: Primer

- However, glass plates used not radiation hard (getting brown)
- Preparation of new test glueings using radiation hard glasses (GI)
- There is one PR-1200 RTV involved APD-crystal currently running temperature cycles in BO:
  - 3 full warm and cold cycles up to now
  - Still properly coupled (stable APD response ratio of 1...)
  - Non primer-coupled APDs lasted 2 full warm/cold cycles maximum

Glueing: Roughen of surface

- Adhesion of couplings improved
  by roughen of involved surfaces (data sheet)
- However, any trial of sanding (1200, 240, 80 grit) or scratching the $PbWO_4$ surfaces obviously deteriorates light coupling
- (We got a lot of $PbWO_4$ test pieces from Giessen...)



Glueing: Vacuumizing

- Vacuumizing the glue given to the photo detectors in order to prevent buildup of air spots during curing
- Does vacuumizing harm the buildup of a strong coupling?
  - Barrel colleagues do not use this technique
  - They apply force on coupling during curing
  - They state to have no problems with bad glueings (however, 1:2 ratio observations!)
- Some discussion with Dow Corning chemists
  - See no reason why not vacuumizing the adhesive
  - Maybe additional time it takes results in skin on cured glue however, pot life 20-60 min (moisture curing!)
  - Anyway, data sheets repeat several times: test for your specific case!
- $\Rightarrow$ Explicit comparison of couplings on $PbWO_4$ w/ and w/o the vacuumizing step

Glueing: Vacuumizing

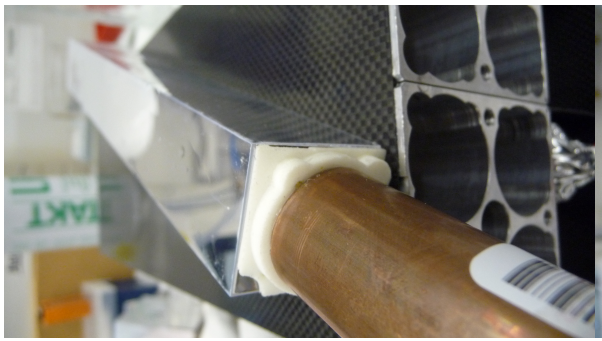
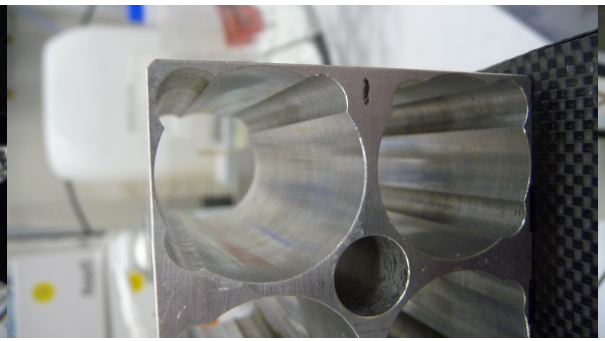
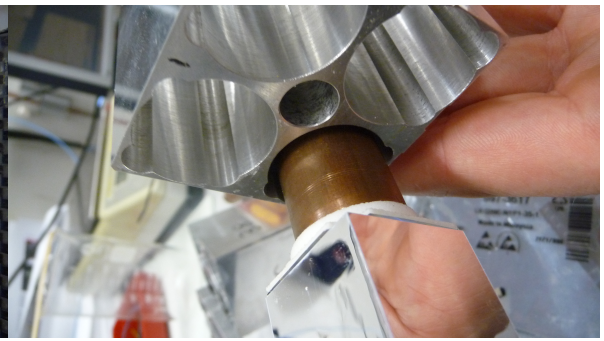
- 5 test couplings:
  3 glued w/o vacuumizing, 2 w/ vacuumizing (no primer)
- Temperature cycling for one week

Sample	Torque to break coupling
not vacuumized 1	3.731 Nm
not vacuumized 2	0
not vacuumized 3	1.441 Nm
vacuumized 1	1.440 Nm
vacuumized 2	1.213 Nm

- No conclusion drawn:
  $\Rightarrow$ repetition of measurement w/ primer (Claudius)

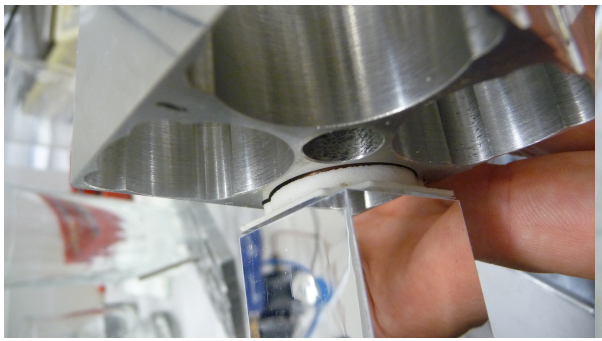
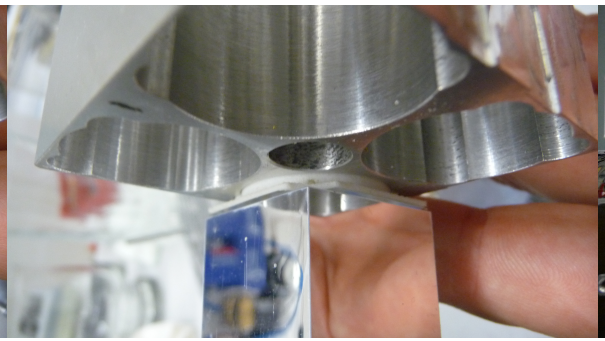
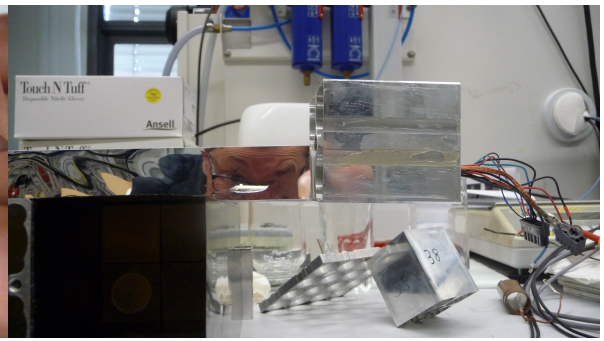
Glueing: Capsule Design

- Forward endcap subunit design: photo detector-crystal coupling part of mechanical structure
- Alveole fix coupled with inserts (glued)
- Crystals may 'float' to some extend inside alveole (sitting on table vs. suspension in forward endcap)
- No mechanical stress on couplings:
  photo detector-preamp unit must not strike inserts!
- Play designed and measured to be sufficient

Glueing: Capsule Design

- Capsule development at some point compromized this design
- Maybe stress applied to the coupling via capsule?
  (To be checked)
- Redesign of capsules? (Omit it w/ VPTTs?)
  - Some of latest APDs (X5) do not properly fit to (some of) the capsules anyway (+0.2 mm, within tolerances)
  - APD surfaces often not in parallel to each other and crystal end face (separate glueing of each APD to crystal first?)
  - Integration of stimulated recovery LEDs...

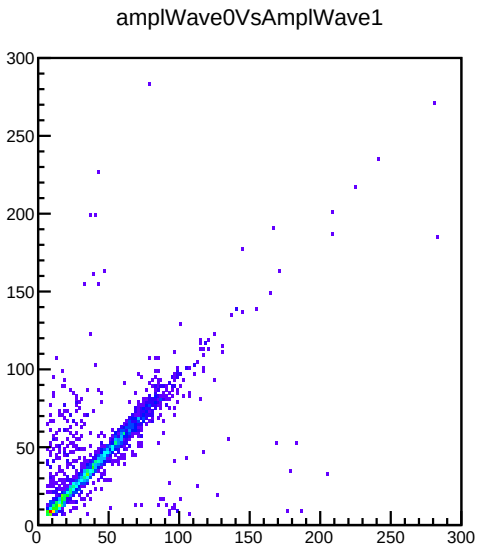




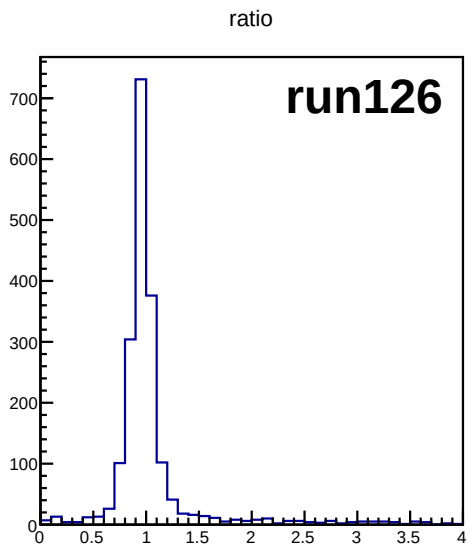
Glueing: The 1:2 Problem

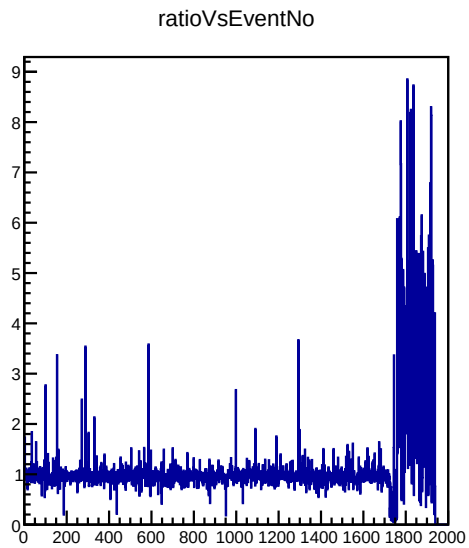
- 1:2 problem of differently responding APD readout on the same crystal
  - Obviously caused by photo detector-crystal coupling
  - It seems that one (two) APD(s) (fully?) decouple during cooling down, resulting in response ratio about 1:2
  - Not fully understood what is going on
  - Why decouple APDs either totally (or at least always to the same amount) or not at all? $\Rightarrow$ Either ratio 1:2 or 1:1

Glueing: The 1:2 Problem

- Typical scenario of APD ratio measurement with properly glued 2-APD-preamp unit
- HV channels adjusted to APD gain of 200 each
- Response APD 1 (“red”) vs. response APD 2 (“blue”): bisecting line, ratio 1:1
- Response ratio histogram: peak around 1
- Time evolution of ratio (event number): constant around 1
- (Event numbers $>$ 1700: Oscillating preamp)

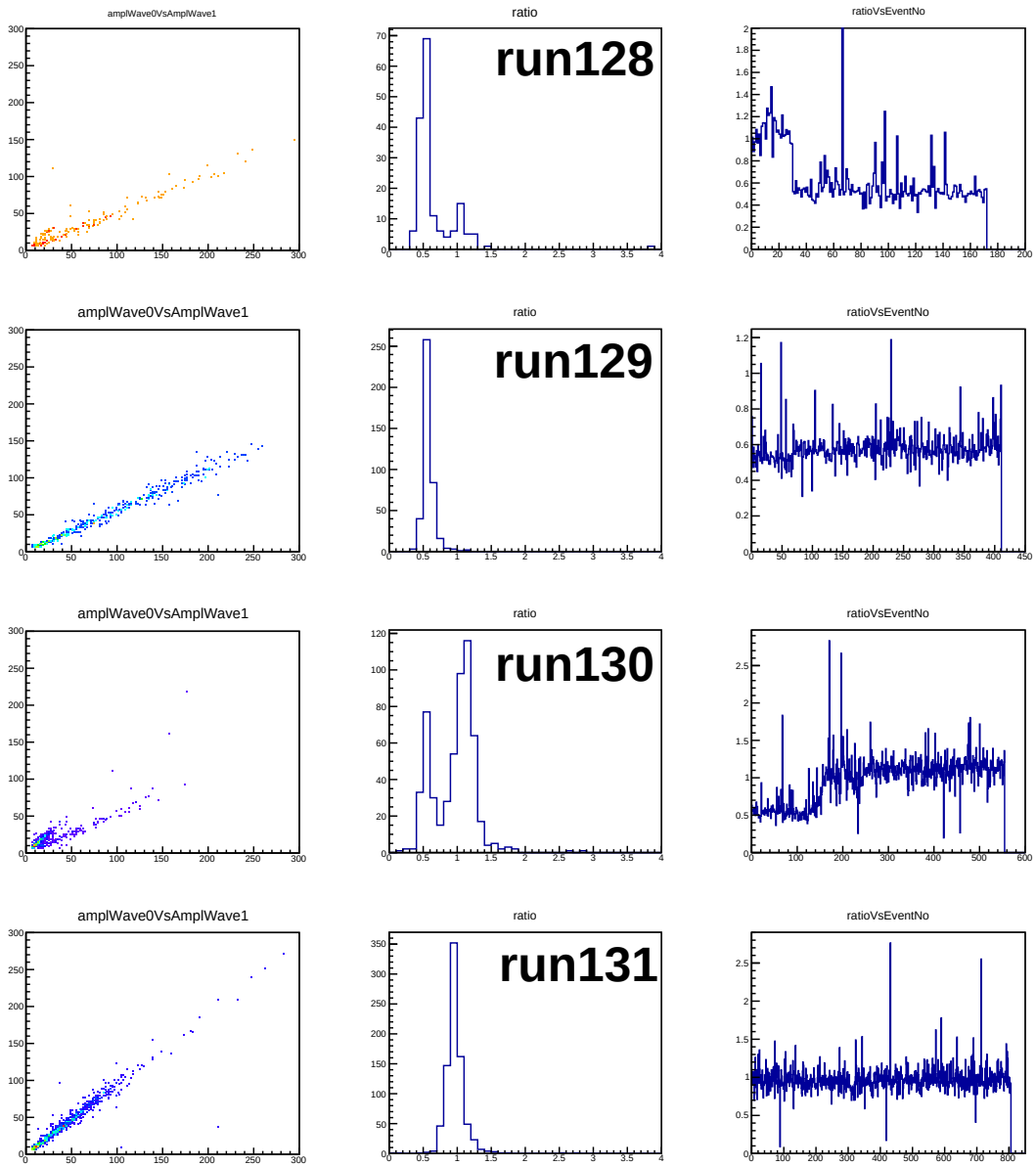






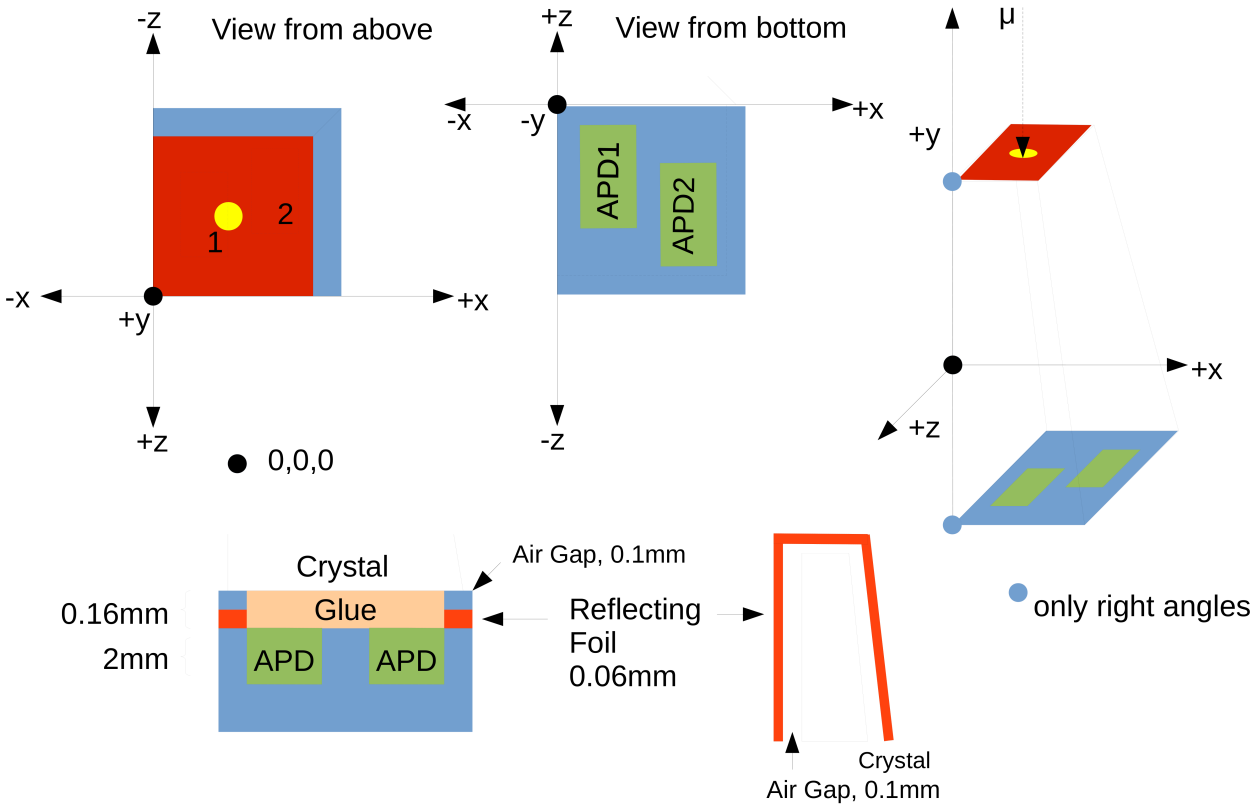
Glueing: The 1:2 Problem

- Started properly coupled, warm, ratio 1:1
- Run 128: cooling down
- Run 129: kept cold, ratio 1:2
- Run 130: warming up
- Run 131: kept warm, ratio 1:1 (usually 1:2)
- “Sudden” jumps while cooling (warming)



Glueing: The 1:2 Problem

- MC simulation of forward endcap crystals (T. Schröder)
- Based on barrel crystal simulation by S. Diehl
  - Crystals wrapped in reflective foil
  - 2-APD readout
  - Glue layer between APDs and crystal

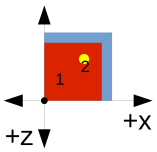


Glueing: The 1:2 Problem

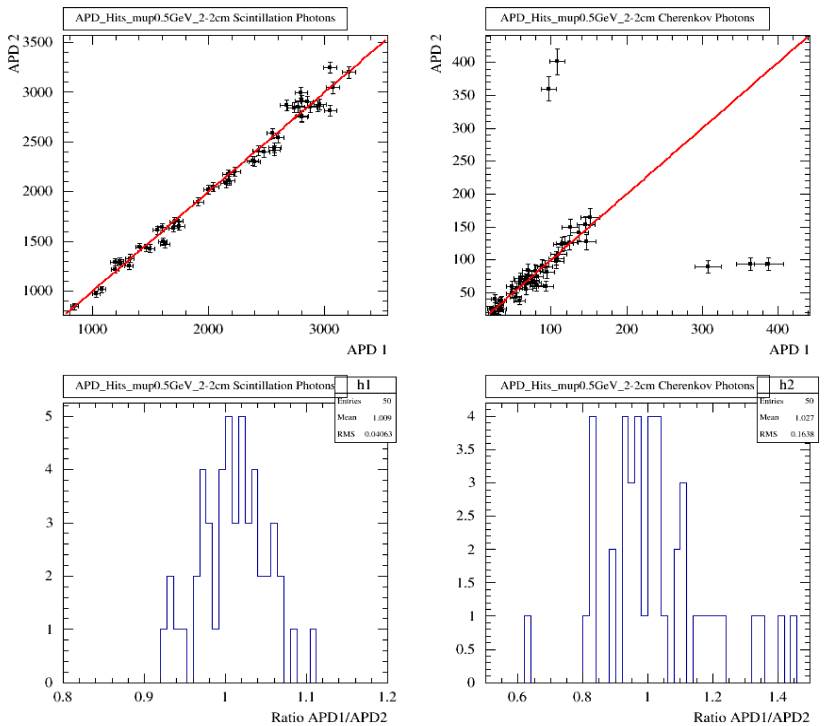
- Different scenarios simulated: myons, electrons, energies and incident (point, angle) varied...
- Cherenkov light considered (4...5 %)
- No differences in APD responses observable!

Mean # Opt. Phot.
Scint Crys 26374
Scint Win1 2122
Scint Win2 2108
Chere Crys 8375
Chere Win1 91
Chere Win2 86

Muon
50 Events
0.5 GeV
Particle Gun
2, 20, -2 cm
0, -1, 0



Myon 0.5 GeV, top edge

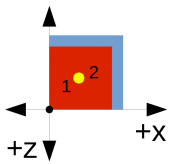


Glueing: The 1:2 Problem

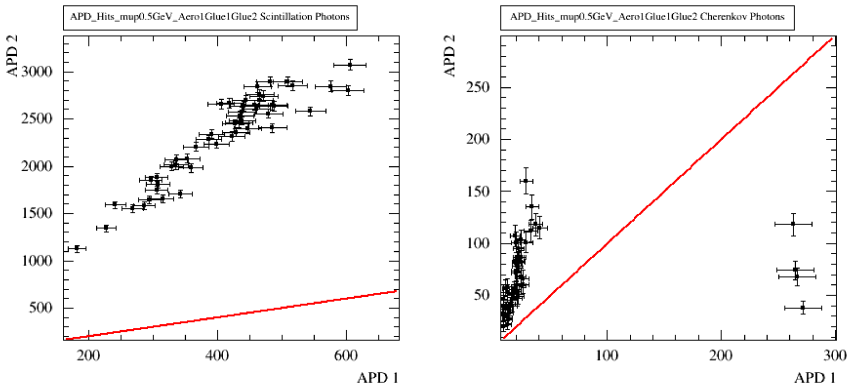
- Adding an air gap between crystal and glue for one APD:
  - Loss of response of 'air plus glue' coupled APD!
  - However, response ratio higher than seen: 1:5 rather than 1:2
  - Do the APDs decouple only partially?

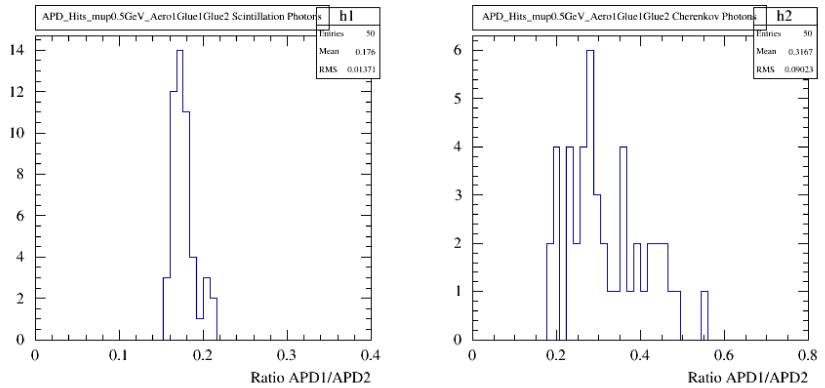
Myon 0.5 GeV, top central, APD1: air+glue

Muon
50 Events
0.5 GeV
Particle Gun
1.2, 20, -1.2 cm
0, -1, 0



use same random seed



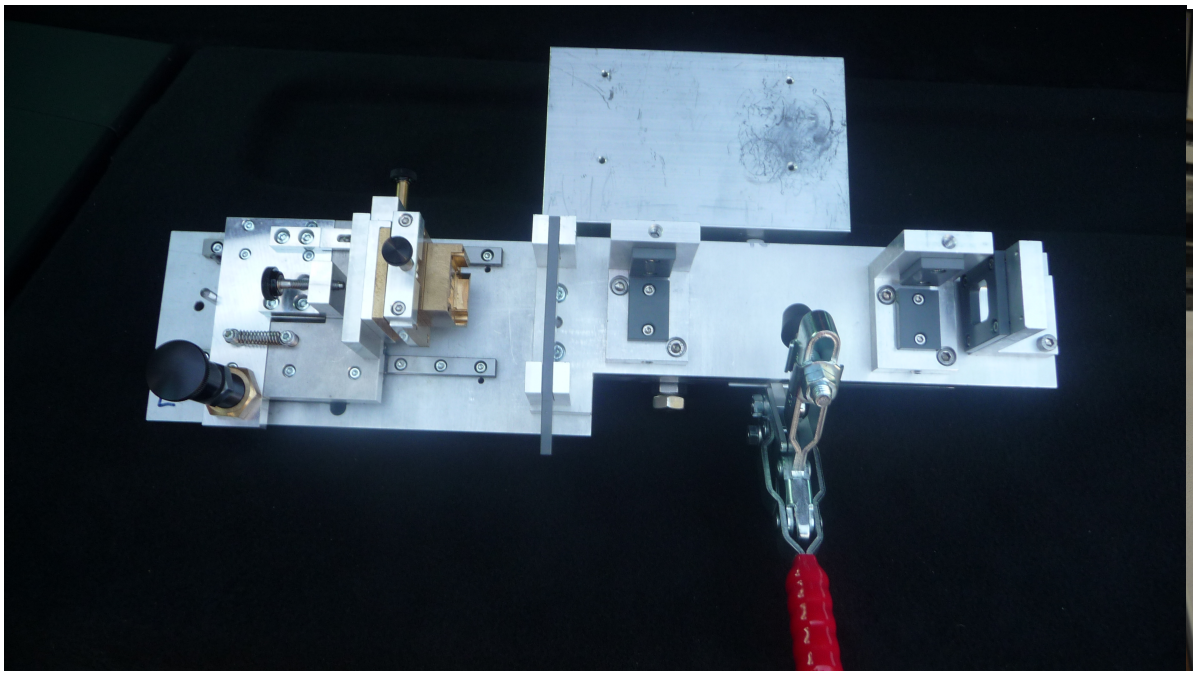


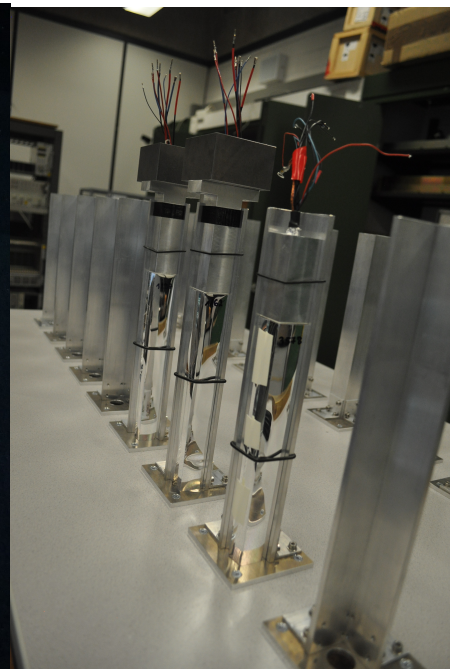
Glueing: Comparsion of Barrel and Forward Endcap Strategies

- Barrel people report to not have any 'glueing issues'
  - No problems with failing couplings
  - However, substancial amount of 1:2 ratio observations: 4 out of 18 crystals
  - There is a 'rotary tool' to remove glued APDs!
- Fundamental differences to FE:
  - Photo detector-crystal coupling no integral part of mechanical structure - ASICs separately mechanically suspended, flexible cable in between
  - No vacuumizing step in glueing procedure
  - Instead: Pressing APDs against crystal during curing
- GI: No intention to additionally use primer fluids to improve adhesion

Glueing: Comparsion of Barrel and Forward Endcap Strategies

- Curing Times: GI: 3 h (pressed) vs. BO: 1 week (no pressure)
- Bochum glueing gauge: weights for pressed glueing (testing)

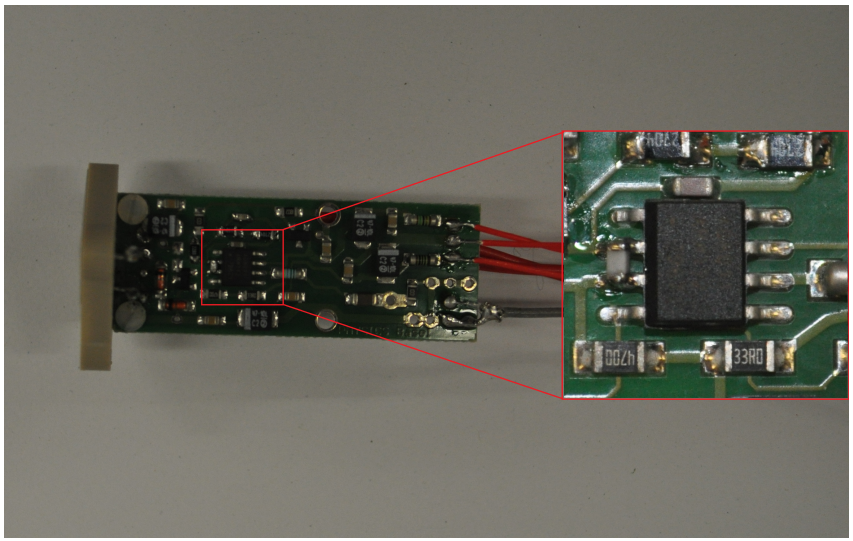




- Climate conditions in laboratories? (moisture)

APD Preamps

- Final APD preamp version tested and accepted
- No susceptibility to ringing/oscillation anymore
- Nice, low (pickup) noise output signals
- Bonn cosmics test unit equipped with such preamps now
  - Currently under construction (glueing)
  - Results of cosmics measurement: confirmation of necessary APD preamp gain

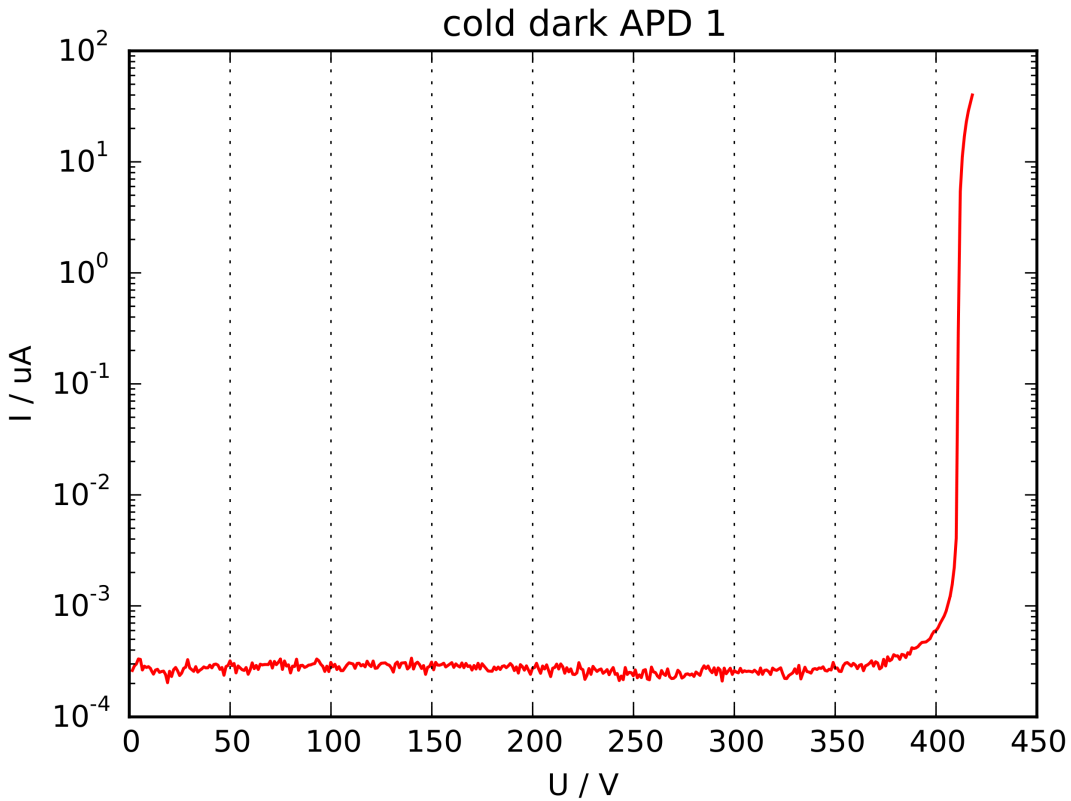


APD Screening for Bonn Tests

- Bonn cosmics measurement setup:
  - Subunit equipped w/ two APD crystals (4 APDs)
  - What preamp output signal results from vertically crossing muons in upright standing crystals?
  - Another method of determining the optimum preamp gain to properly cover full energy range
- Measurement somewhat delayed as old preamps heavily oscillated (and APD-crystal couplings failed)
- The four corresponding APDs have been fully screened:
  - Dark current
  - Light current(s), intensities
  - Warm, cold measurements
  - AC, DC signals
  - All light signals referred to reference
- All measurements done using ISEG HVs (Problems: Talk T. Triffterer)

APD screening: Dark Current at Breakdown?

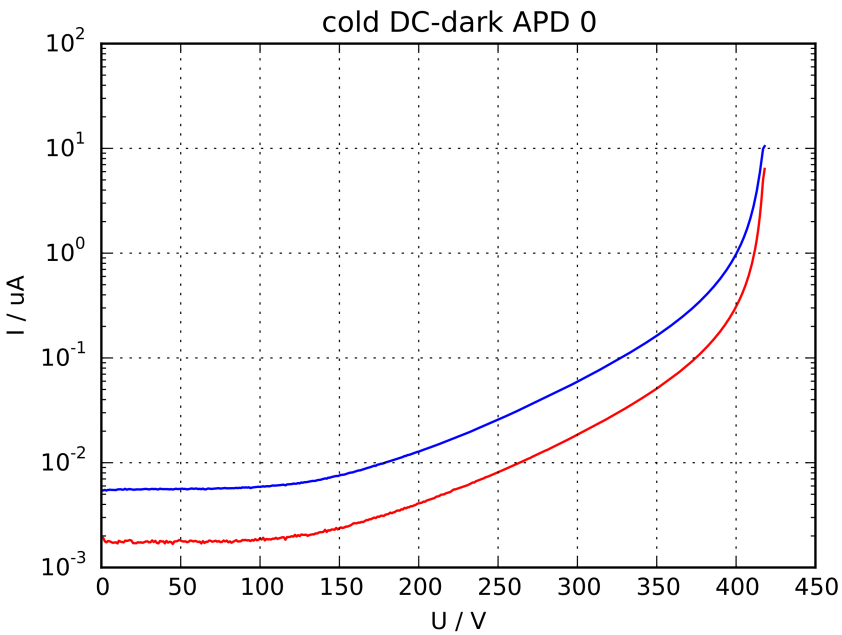
- Breakdown voltage definition: U_{break}=U(I_{dark}=100 μA)
- Steep rise in dark current even at lower bias voltages, close to operation point (M=200)

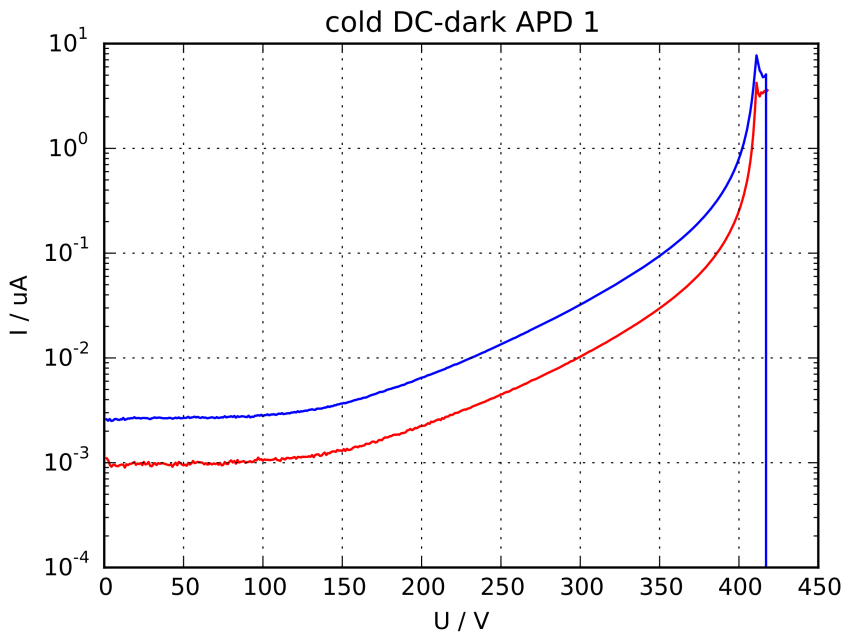


- However, no influences on operation at gain 200 seen yet

APD screening results: DC saturation?

- Gain curves bend at 'high' DC light intensities and 'high' bias voltages (i.e. 'high' DC currents)
- Non-linearities caused by saturation effects?

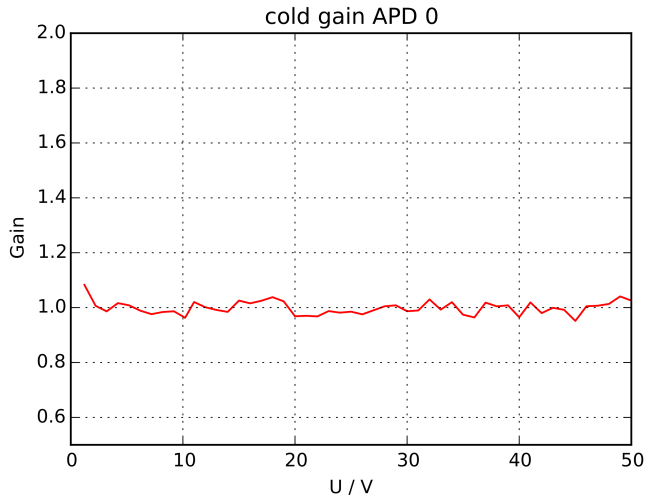


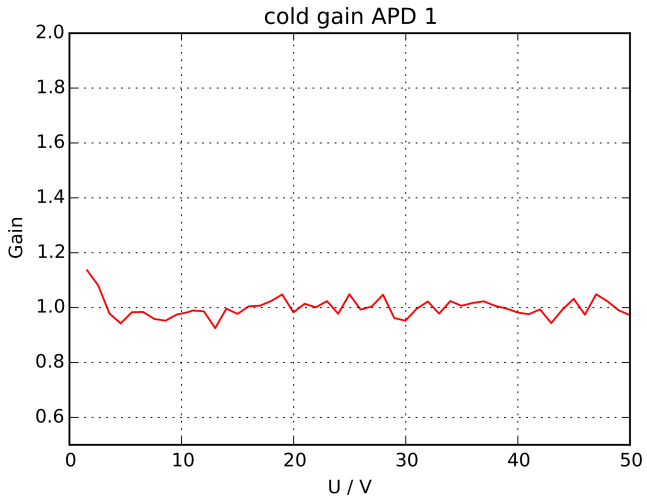


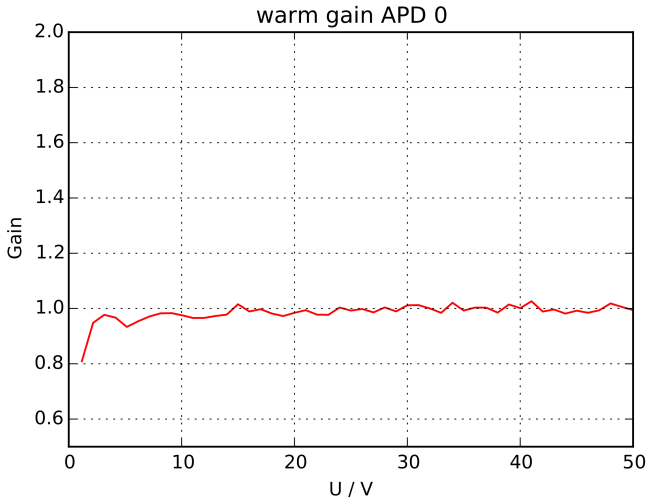
- $\Rightarrow$ Considered 'red' low-DC intensity curve for AC/DC comparison

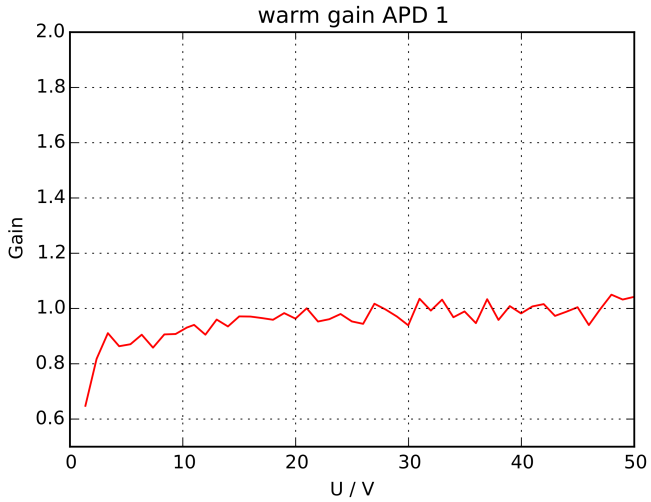
APD screening results: DC normalization

- Gain 1-normalization: fit to curve between 30 V and 50 V



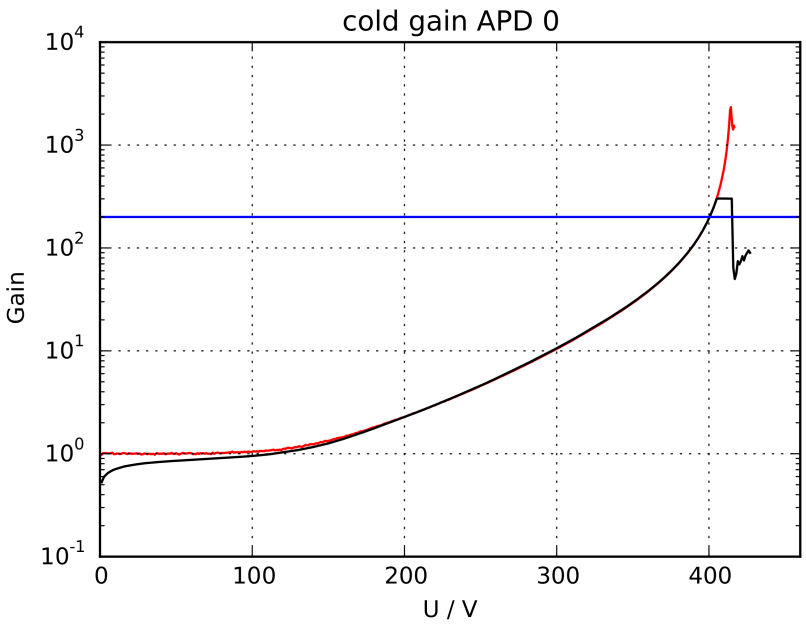


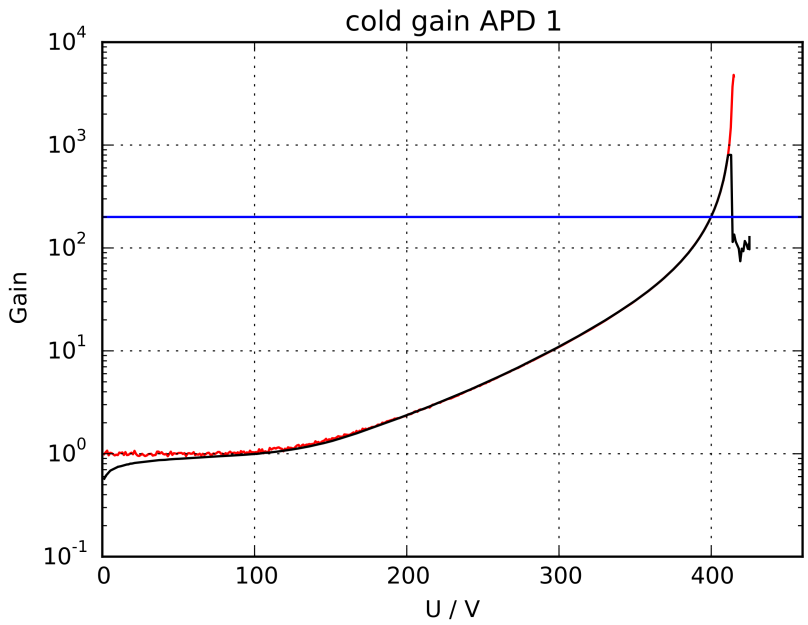




APD screening: AC vs. DC

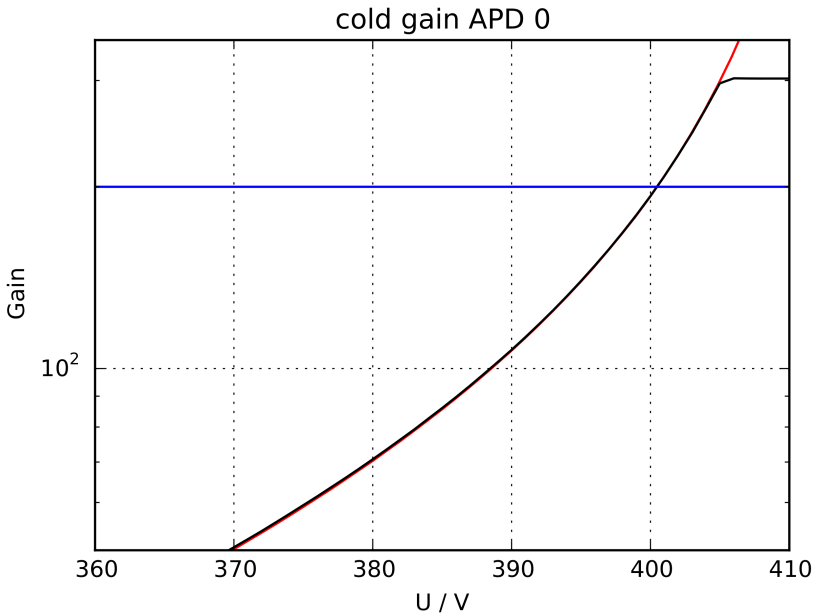
- AC and DC gain at -25 °C
- Normalization: $M_{AC}^{200} := M_{DC}^{200}$
- Nicely overlapping curves except for the low voltage end (APD-, coupling-, preamp input-Cs charge/voltage diviation)
- Result of 'low intensity' DC screening?

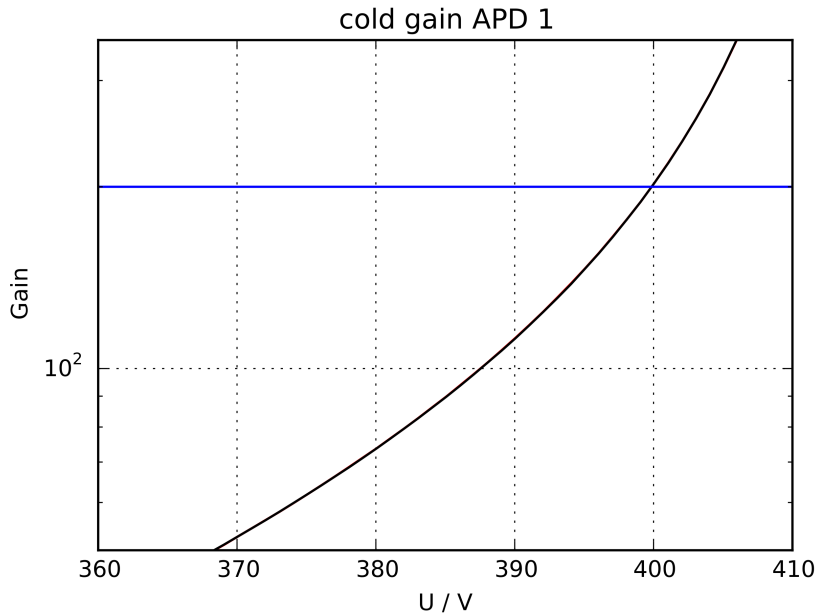




APD screening AC vs. DC

- Zoomed into operation bias voltage region:





- To do:
  - Check gain curves at different AC intensities
  - Check responses of APDs to the same AC signal ($M^{200}_{AC} := M^{200}_{DC}$ fine?)

Summary

- Glueing:
  - We need to refine the glueing procedure (chemically, mechanically) before start of mass production
  - Primer does improve adhesion
    - Enough for our needs?
    - Is transparency compromized?
    - Is primer prepared coupling radiation hard?
  - Capsule redesign (stress on coupling, space for APDs, LEDs)?
  - There are very strong hints from experiment and simulation that the "1:2 problem" is a coupling problem
- Long-lasting preamp ringing problem finally solved!
- APD screening
  - Do the AC-DC screening discrepancies come from saturating DC screening intensities?
  - Need to check with different AC intensities and constant intensities on different APDs