

# Update on Barrel EMC Developments and Planning of Barrel Slice Assembly



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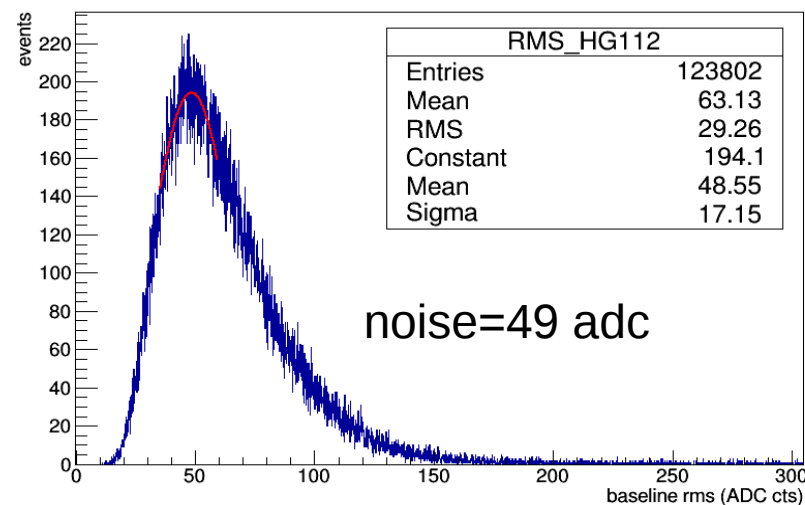
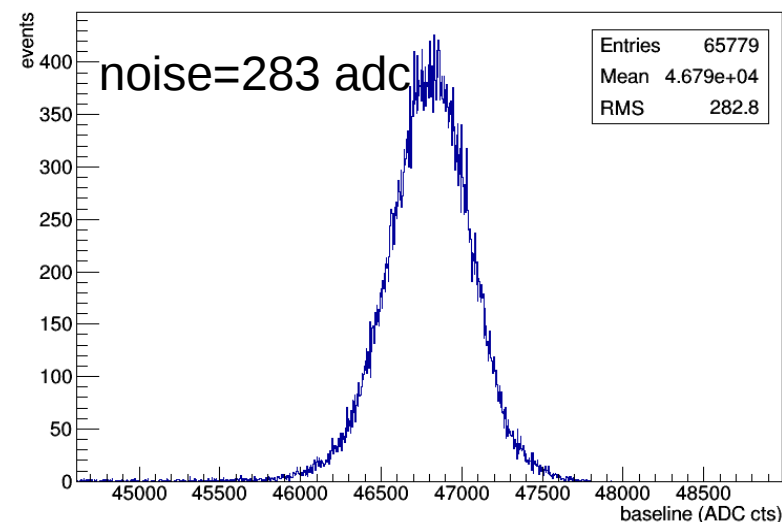


PANDA CM, 08-Jun-2016

# Noise

## Two types of relevant noise definitions:

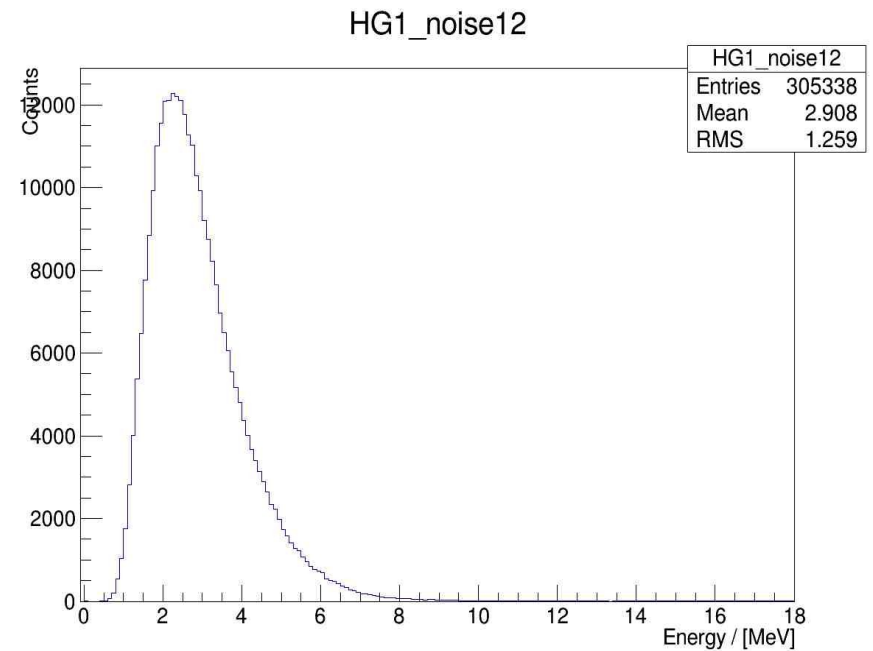
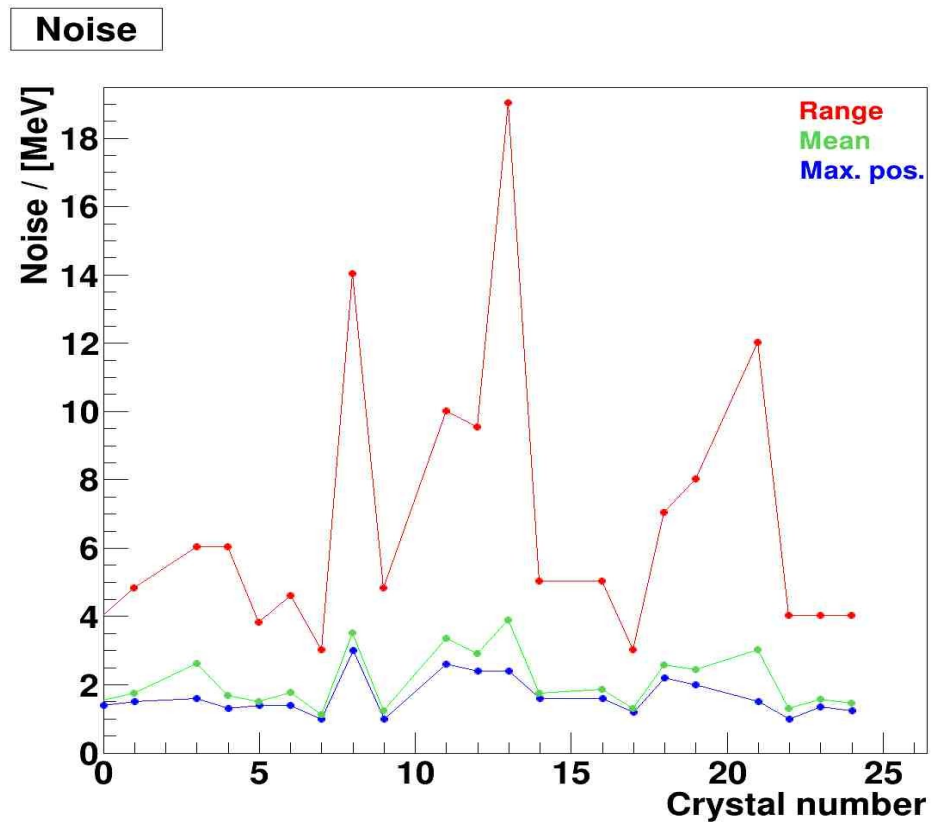
- Distribution of baseline mean values
  - Indicates the presence of low frequency fluctuations (EMI, pick-up etc.)
  - Less relevant for event-by-event reco due to adaptive BL
- Distribution of baseline rms values
  - characterizes the noise relevant at signal timing and sampling frequencies
  - Determines the lower bound of the signal noise



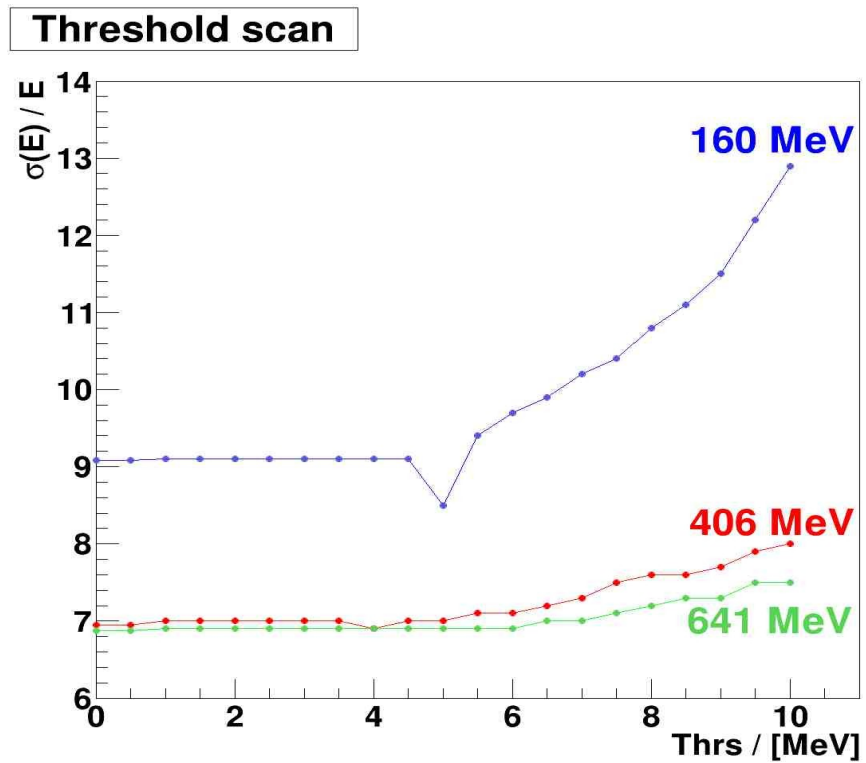
# Noise

## With calibration from cosmic run

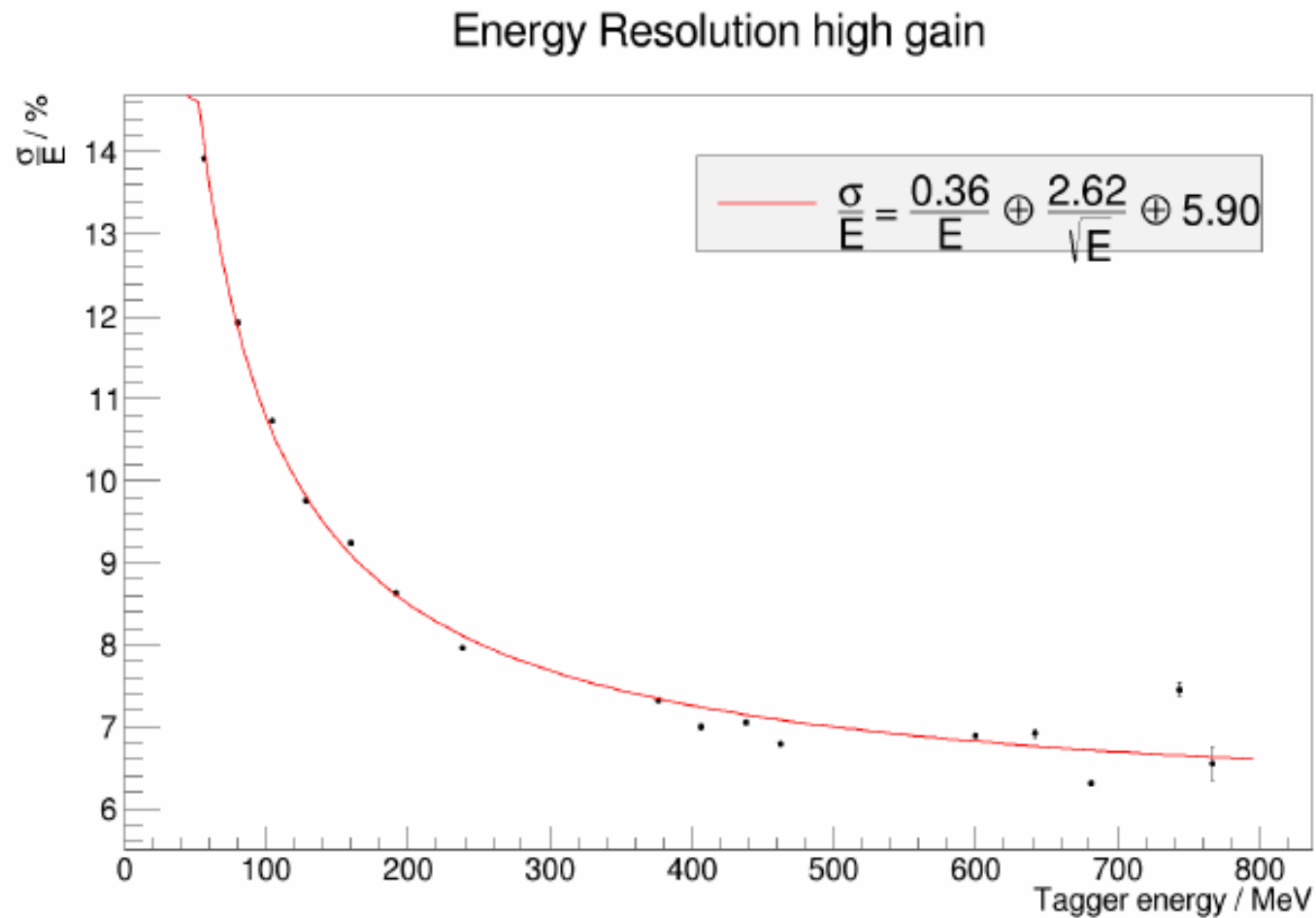
- Distribution of baseline mean values



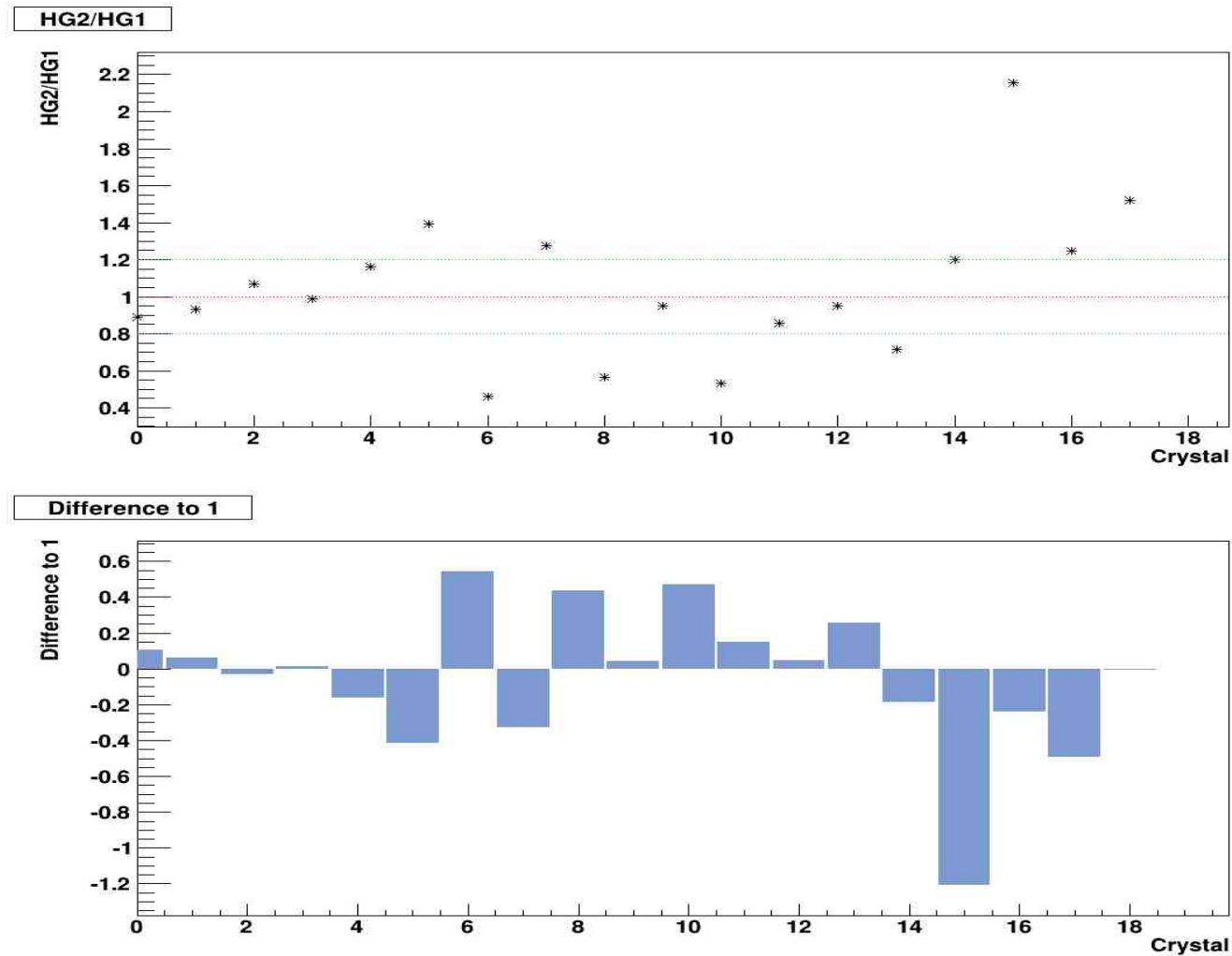
# Threshold



# Energy Resolution (3x3 matrix)

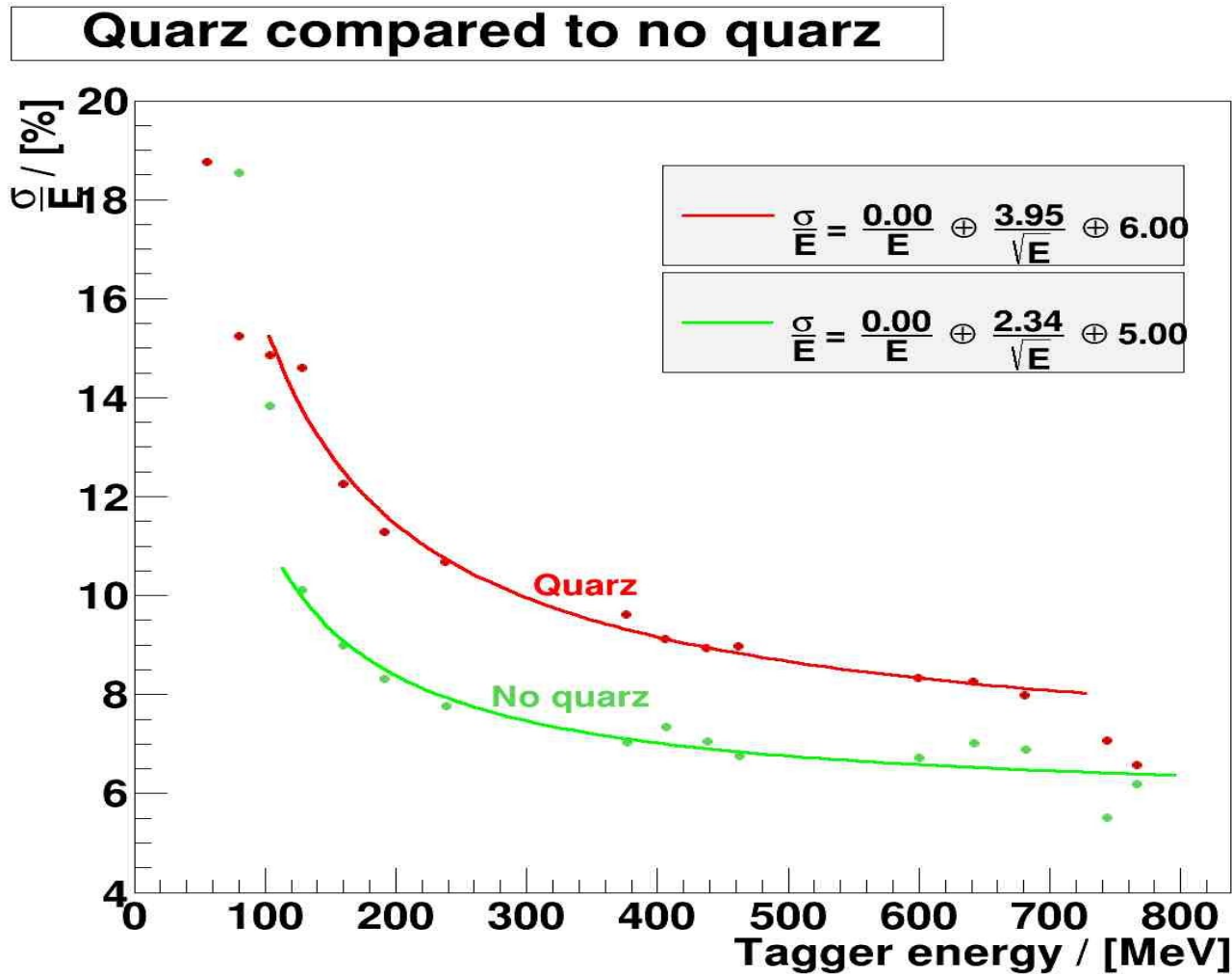


# APD gains



- Ratio of the gains of 2 APDs of one crystal

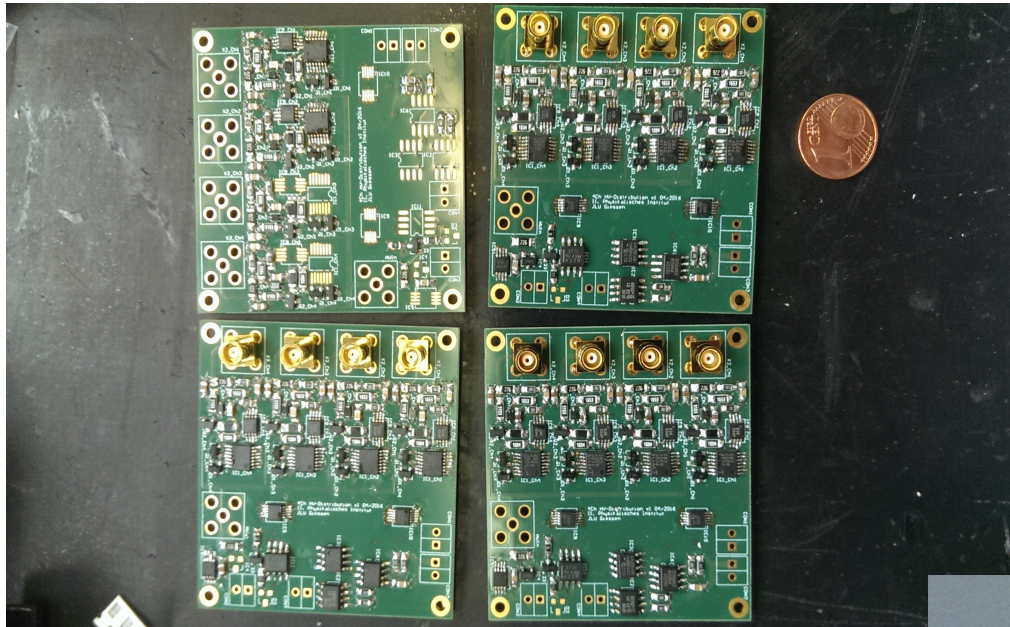
# Energy Extraction



- Energy resolution with 1.5 cm quartz radiator in front of EMC



# HV Distribution

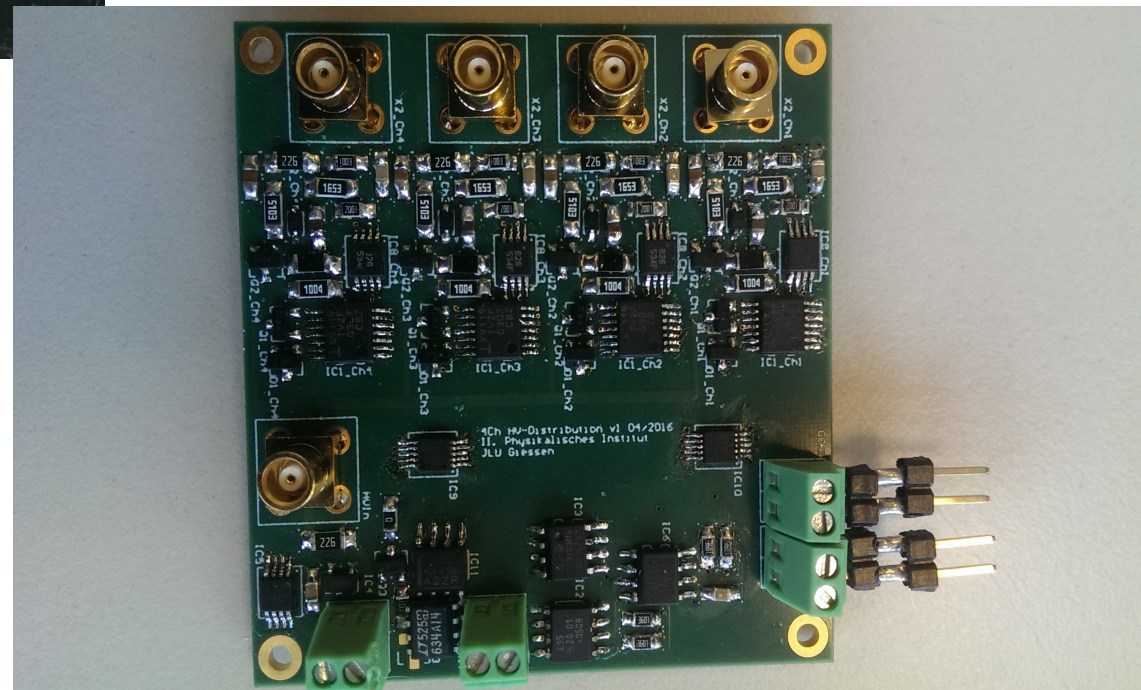


Distribution of APD bias voltage from one HV cable to 4(8) APDs

Close to detector → compact, rad hard

High side shunt regulators for voltage control of individual outputs

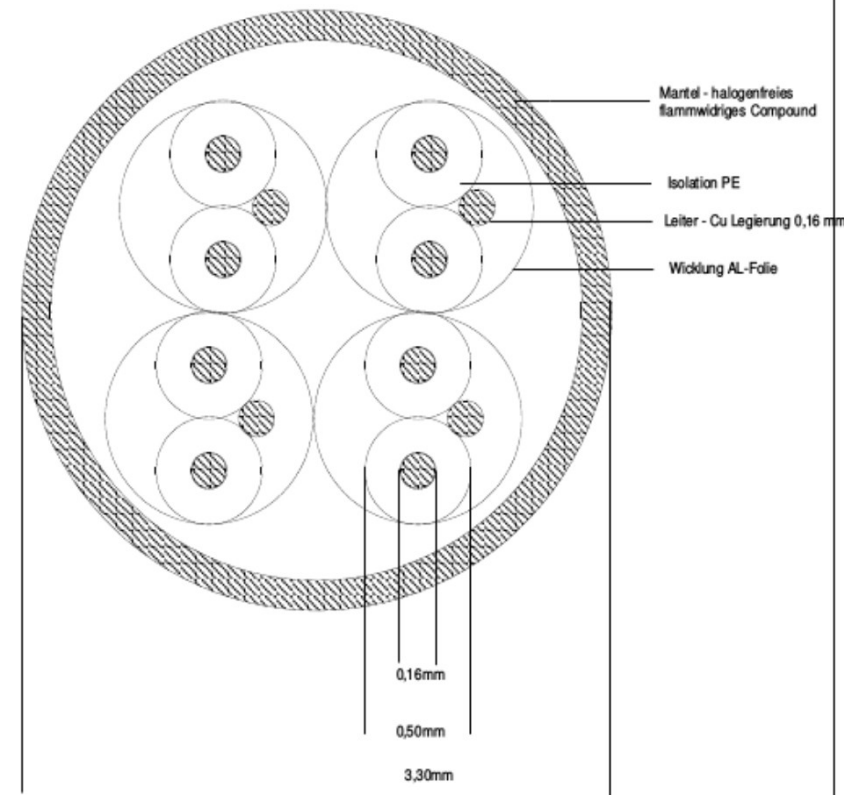
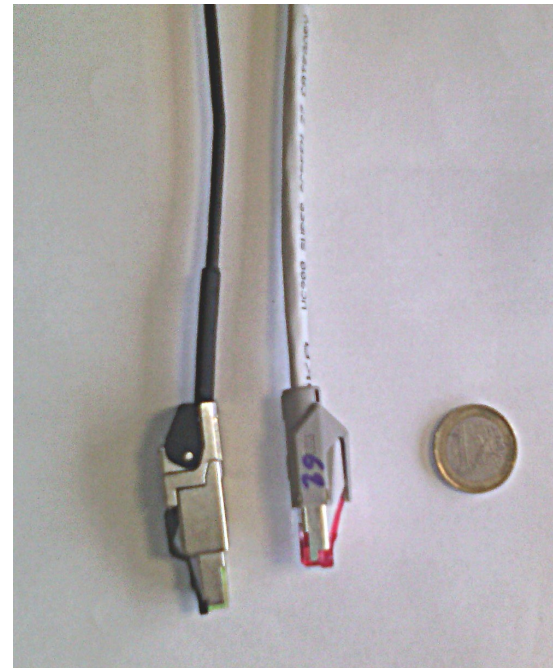
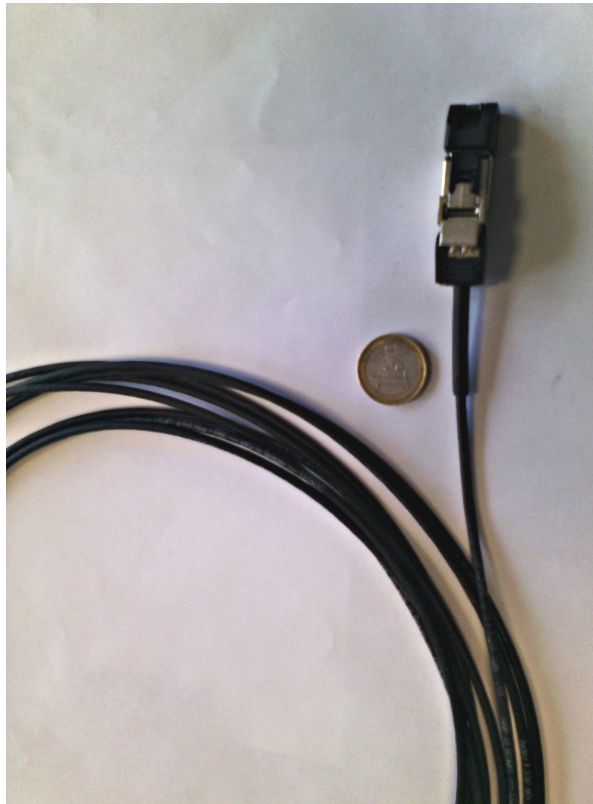
- 2nd prototype with final geometry available
- 4 channels, all functions verified and ok
- Irradiation tests scheduled with gamma and neutrons
- 3rd prototype: → 8 channels





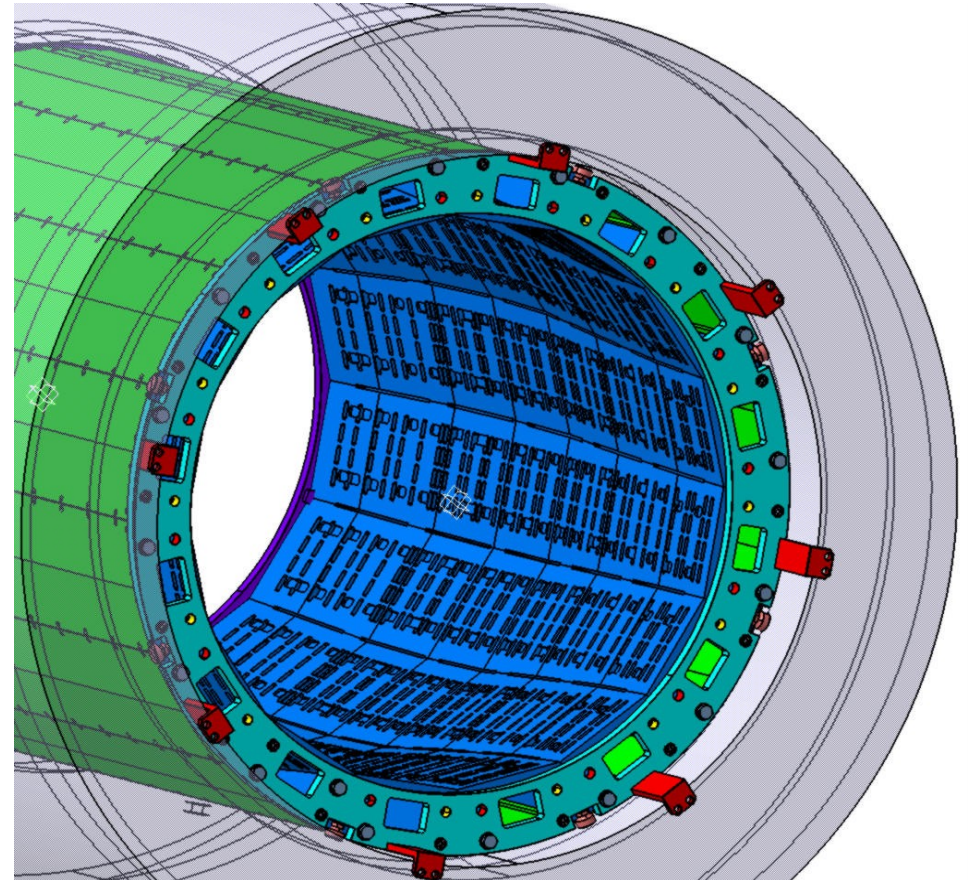
# Test of new signal cable

- Development of ultra-thin differential cables started with company BEDEA (Asslar/Germany)
- First prototype with stainless steel cores (0.1mm): attenuation too high
- Second prototype produced in May 2015 with copper cores (.16mm) and improved mechanical stability



# Cable Routing

- Available opening in slice end face for services:  $17 \times 9 \text{ cm}^2 = 15,300 \text{ mm}^2$
- 720 signal cables + 1 slow-control + 1 HV cable = 1080 cables, 3.3 mm diam.
- Required cross section for cables:  $13,900 \text{ mm}^2$  (including fill factor)
- Leaves  $1400 \text{ mm}^2 = 3.7^2 \text{ cm}^2$  for remaining electric services
- Saving of cross section possible: introduce SC-distributors within slice volume

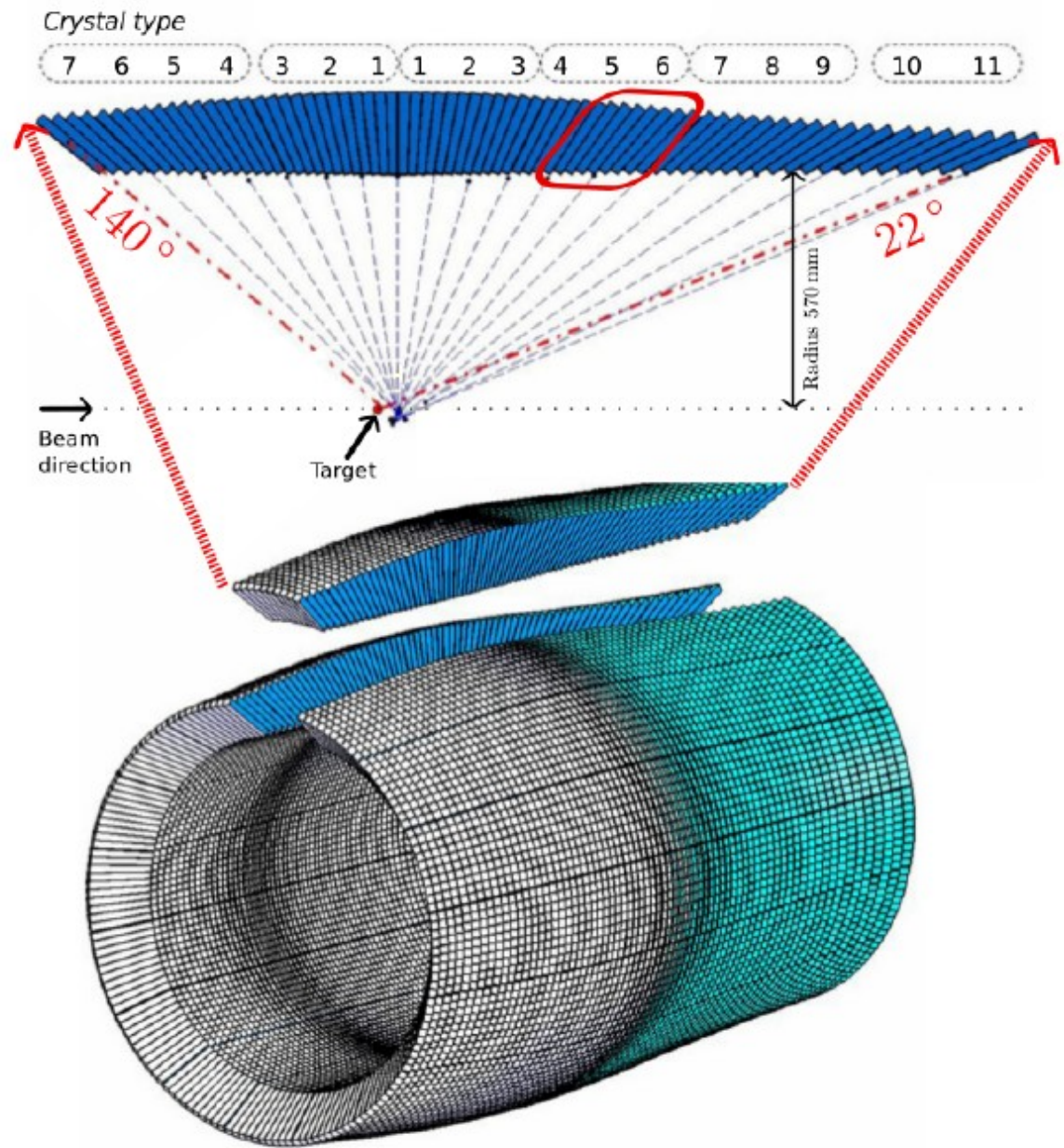




# Barrel Slice

## Assembly of one full Barrel EMC Slice until Q2/2017

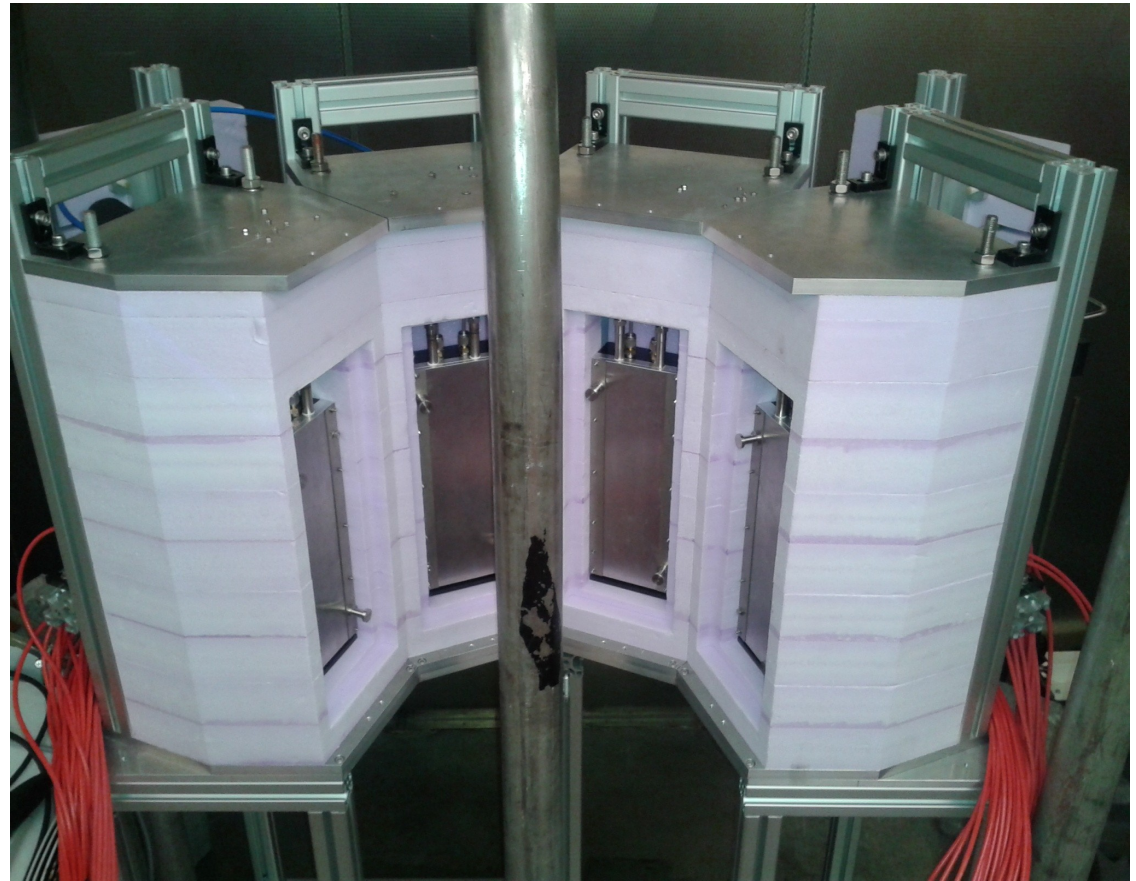
- 710 crystals in 11 different geometries
- 1420 APDs after 1st screening, irradiation, 2nd screening and matching
- 360 left and 360 right handed APFEL-ASIC flex PCBs
- 4500 m of signal cables



# Barrel Slice

## APD irradiation @Giessen

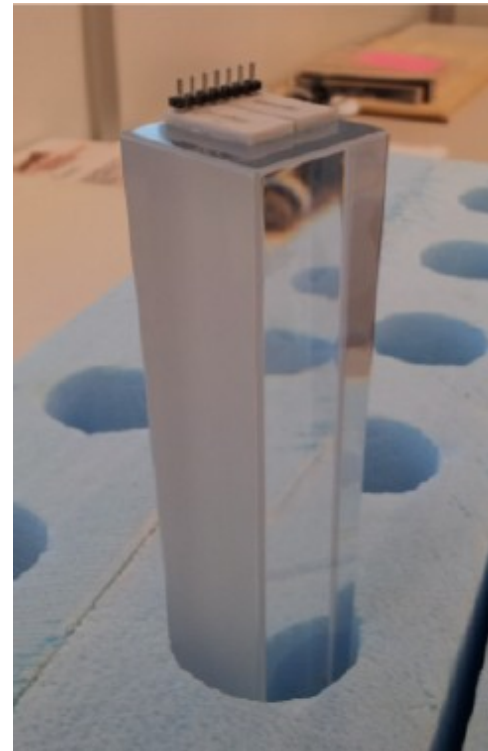
- $^{60}\text{Co}$  source: 50 Gy/h
- Irradiate 80 APDs / day @ 30 Gy
- Irradiation at RT, transport at  $-18^{\circ}\text{C}$ , Annealing in oven with  $80^{\circ}\text{C}$



# Barrel Slice

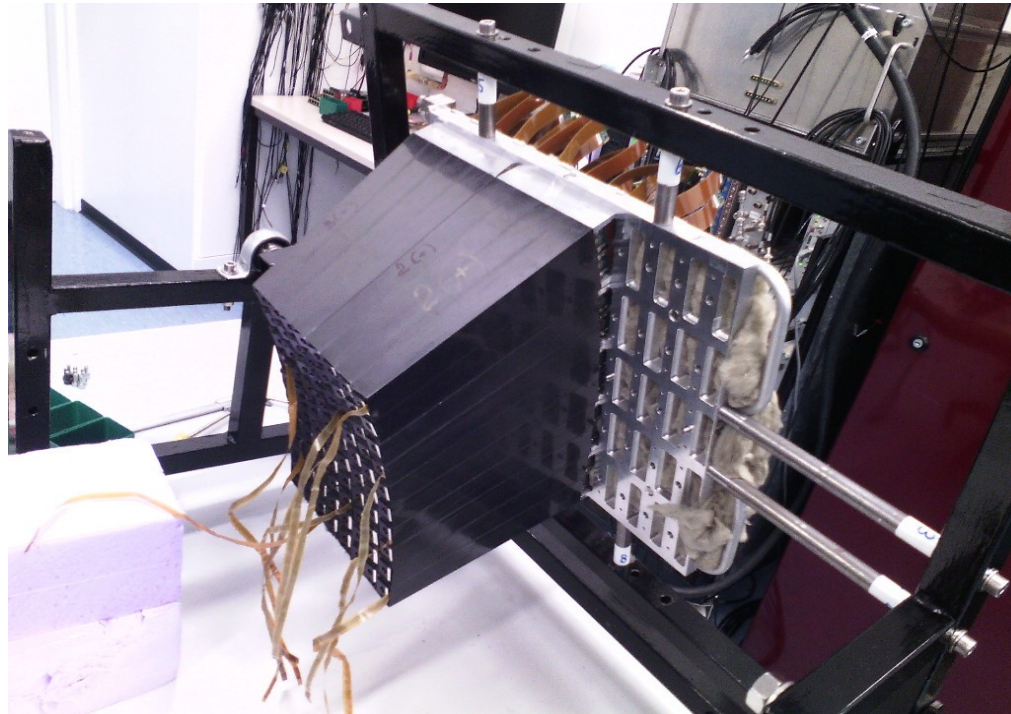
## Glueing and wrapping of detectors

- 4 glueing stations available, 4 more to be assembled
- Throughput: 40 crystals (=one module block)/week
- Total processing time 18 weeks
- Reflective foil available, laser cutting and processing to be ordered





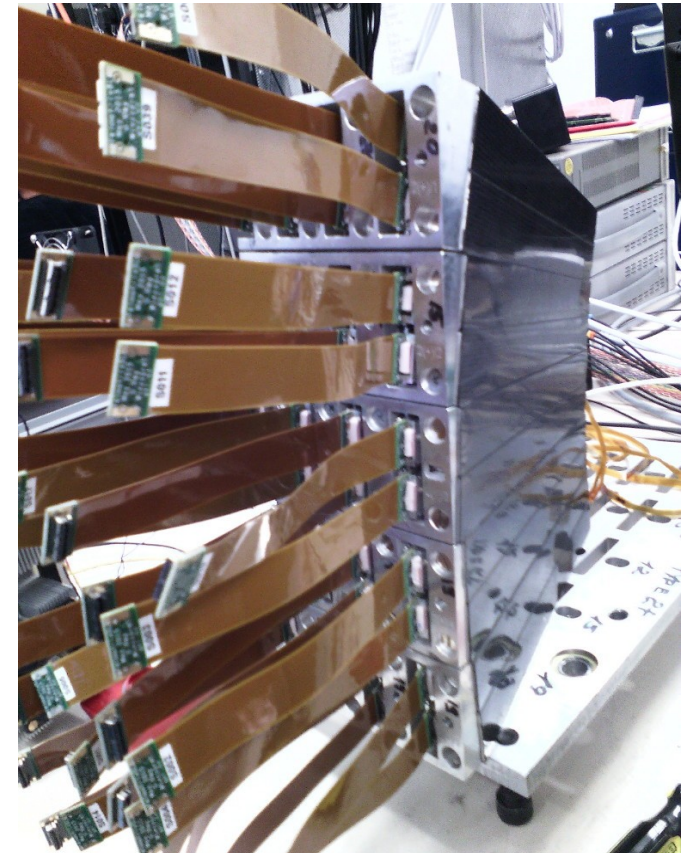
# Barrel Slice



- Assembly of 2 crystal blocks (type 2 and 3) already done
- 80 crystals equipped with matched pairs of APDs based on information from APD database



- ASIC flex PCBs v6 with left- and right-hand connector configuration



# Assembly Schedule

	2016							2017					
	6	7	8	9	10	11	12	1	2	3	4	5	6
<b>crystal tests</b>													
<b>APDs (2000 pcs)</b>													
irradiation	400/week												
2 <sup>nd</sup> screening	150/week												
matching													
<b>reflective foil production</b>													
<b>capsule production</b>													
<b>detector assembly</b>		40/week											
<b>ASIC PCBs (710 pcs)</b>													
PCB production	1 month + order + vacation time												
mounting/bonding			8 weeks										
testing				90/week									
<b>module assembly</b>													
<b>Backplane PCB (180 pcs)</b>													
design													
testing	testing of prototypes + rad hardness of components												
production													
testing							20/week						
<b>signal cables (890 pcs)</b>													
ordering													
tayloring													
mounting on connector PCBs				38/week									
<b>slice assembly</b>													
module placement													
BPL mounting													
cable routing													
SC & DAQ													
<b>cooling</b>													
installation of Bo cooling													
test with slice													

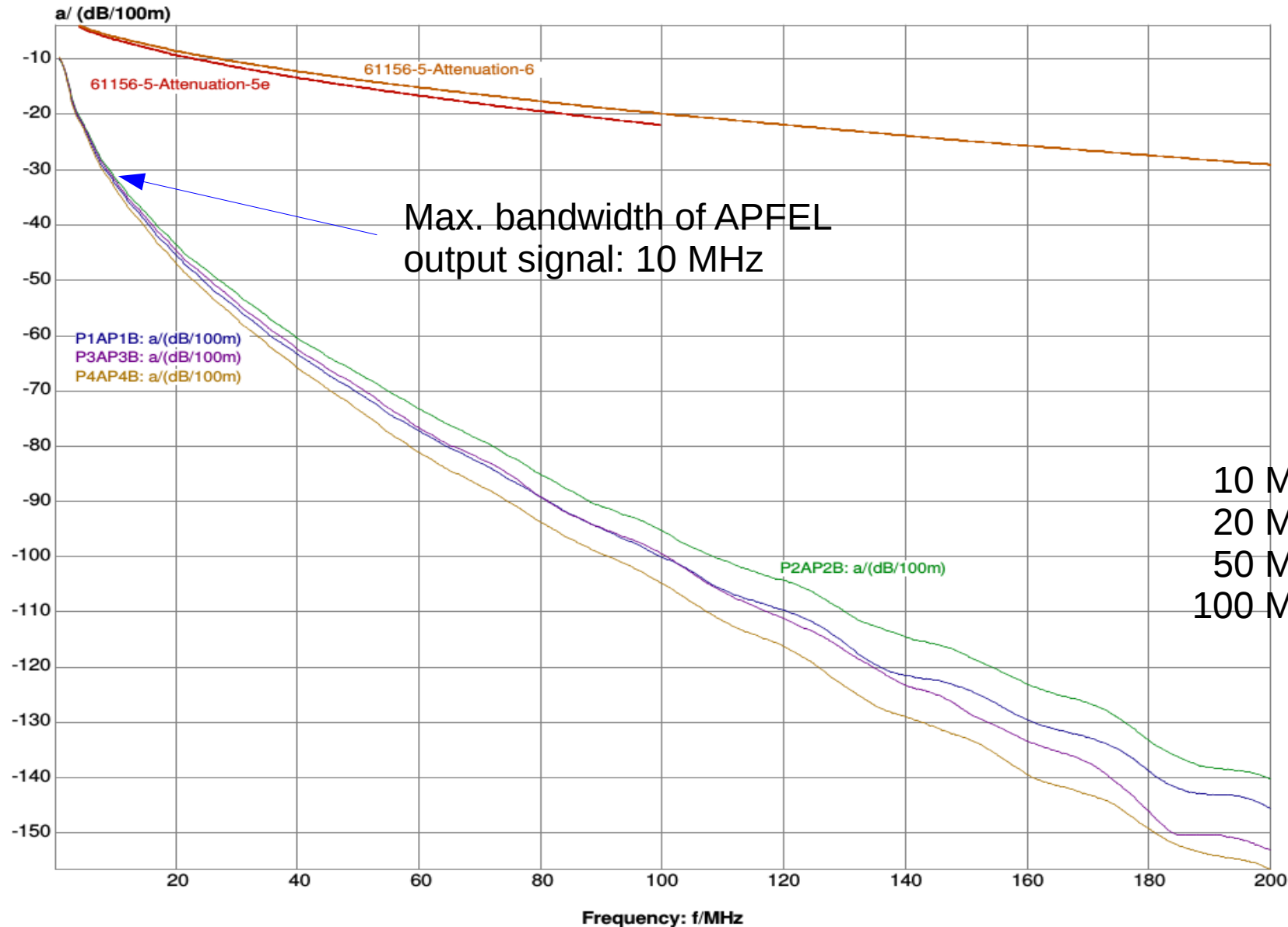


# Backup

# New signal cable - Attenuation

Balanced pair cables (IEC61156-1/-5): Attenuation I(St)2X(PiMF) 4x2x0,16 FRNC 4x2x0,16 FRNC 13026202

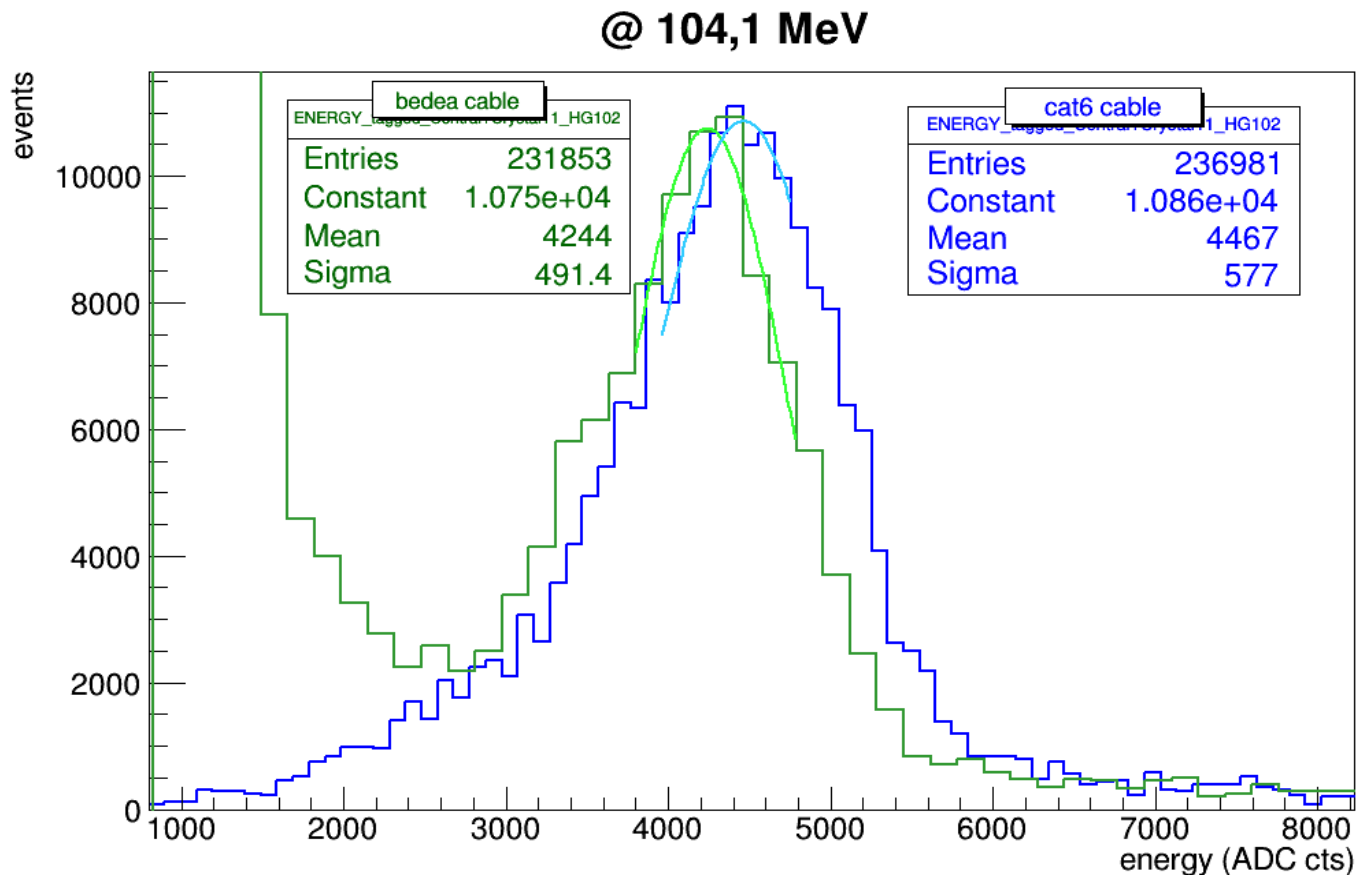
300.0 kHz - 200.0 MHz Test length: 19.50m



10 MHz: .32 dB/m  
20 MHz: .45 dB/m  
50 MHz: .7 dB/m  
100 MHz: 1.0 dB/m

# Test of new signal cable

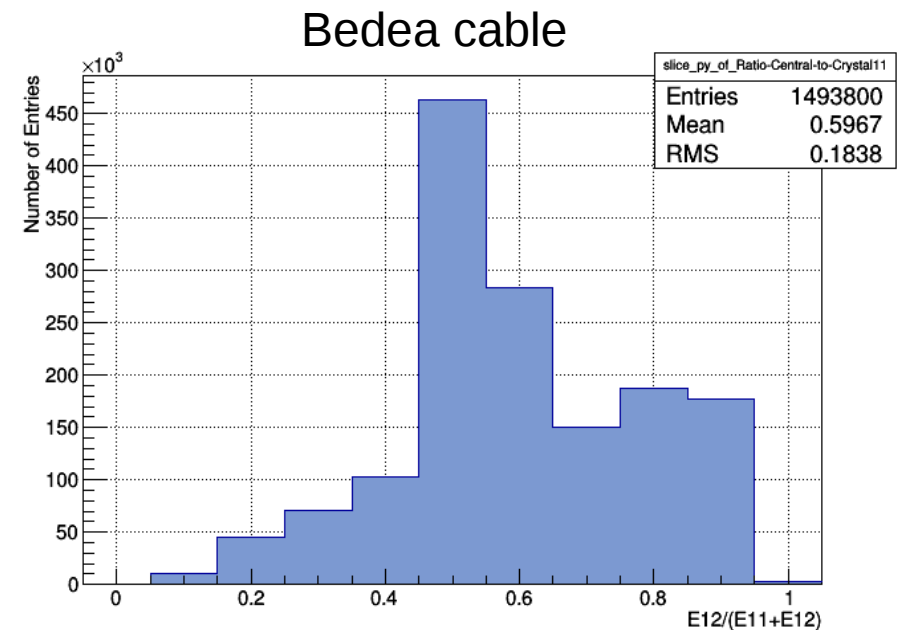
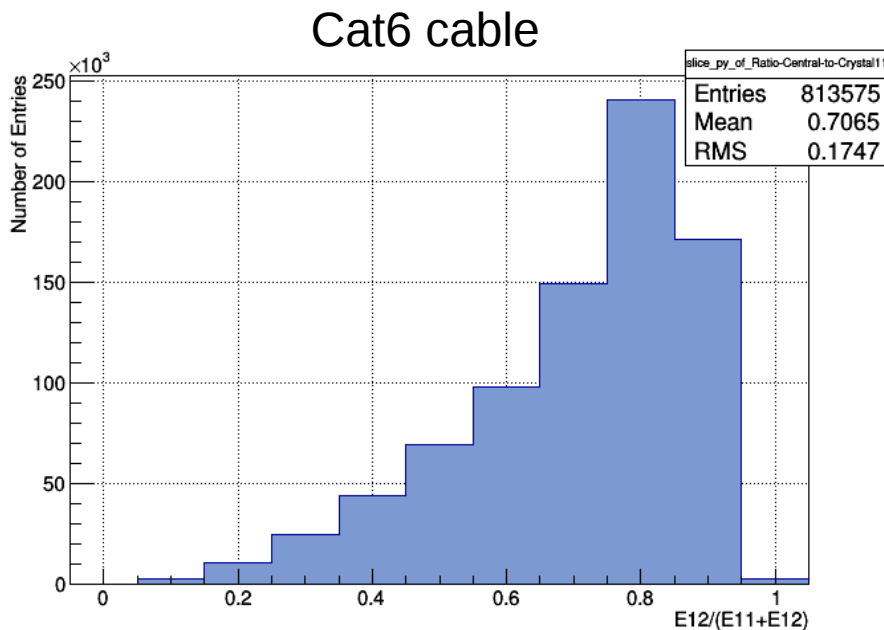
- Comparison of 2-crystal-sum between standard cable (cat6) and Bedea cable measured at the same channel under equal conditions



- Due to summation no direct comparability between the cables

# Test of new signal cable

- Better observable: ratio of energy deposit between test channel and (2-crystal) energy sum



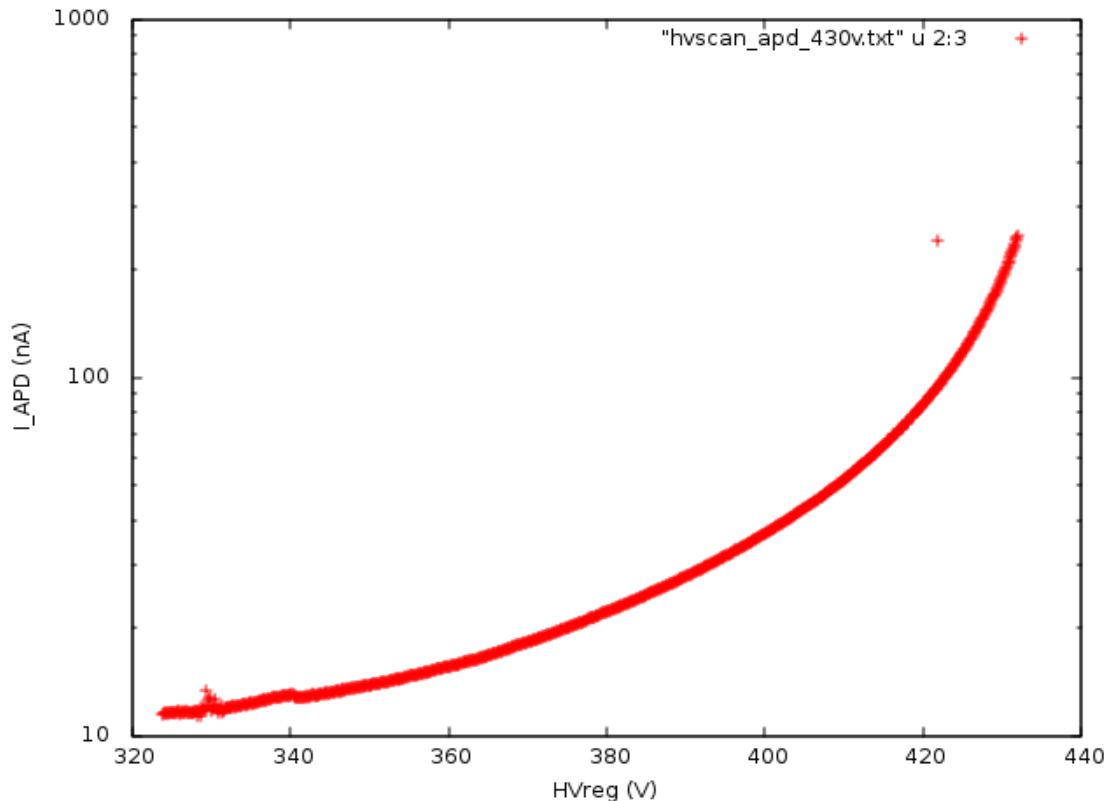
- Derive amplitude ratio of test channel between both cables

$$E_{\text{bedea}}/E_{\text{cat6}} \sim 64\% = -2 \text{ dB} \quad (\text{i.e. 2 dB higher Attenuation than cat6 cable})$$

- **Attenuation of 2 dB within specs**
- **Compensation by modification of line driver gain**

# HV Distribution

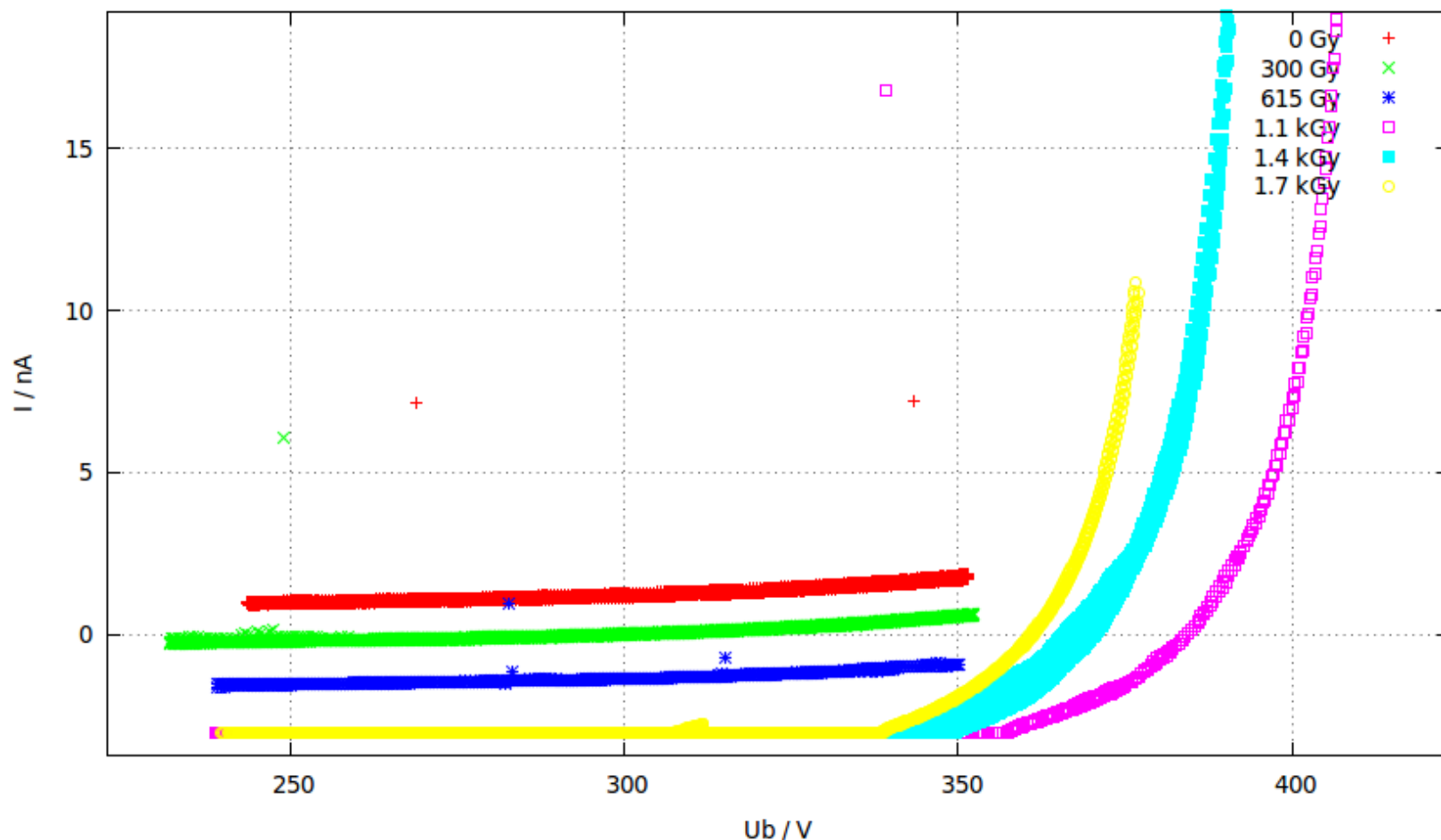
- Regulation of a single channel from HV(In) down to HV(In)-100V with 10bit resolution (0.1V/LSB) I2C Potentiometer
- Measurement of actual APD voltage (17mV LSB, 530V FS) and current (30pA LSB, ca. 1uA FS)
- Scan of HV by stepping through all potentiometer (wiper) settings



```
#ADC1 ch 0: 25129
#ADC2 ch 0: 9368
#Voltage(1) ch 0: 3.141221 V
#Voltage(2) ch 0: 1.171036 V
#*****
#HV: 431.68 V
#Current: 249.2 nA
#*****
#RMeas: 1732.56 MOhm
#L.M75 temperature: 20.5 C
#X9119 WCR 0: 0
#Wiper HV (V) I (nA) R (MOhm)
0 431.917 249.81 1729.013
1 431.826 246.16 1754.255
2 431.742 243.16 1775.572
3 431.670 240.25 1796.737
4 431.594 236.97 1821.282
5 431.501 234.24 1842.103
6 431.433 231.73 1861.829
7 431.340 228.46 1888.039
8 431.276 226.36 1905.284
9 431.166 223.01 1933.399
10 431.108 221.07 1950.115
11 430.996 218.00 1977.083
.....
1014 324.898 11.63 27928.194
1015 324.781 11.66 27848.119
1016 324.695 11.64 27904.390
1017 324.582 11.59 28003.459
1018 324.462 11.57 28038.121
1019 324.365 11.59 27991.208
1020 324.262 11.62 27911.845
1021 324.166 11.60 27935.542
1022 324.043 11.57 28014.777
1023 323.939 11.52 28109.280
```

# HV Distribution

- Several irradiation-measurement cycles done up to 1.7 kGy with  $^{60}\text{Co}$  source
- I/V Characteristic shows shift of measured current towards lower values
- Shift in measured APD voltage towards lower values
- Current clipping at low ADC range limit



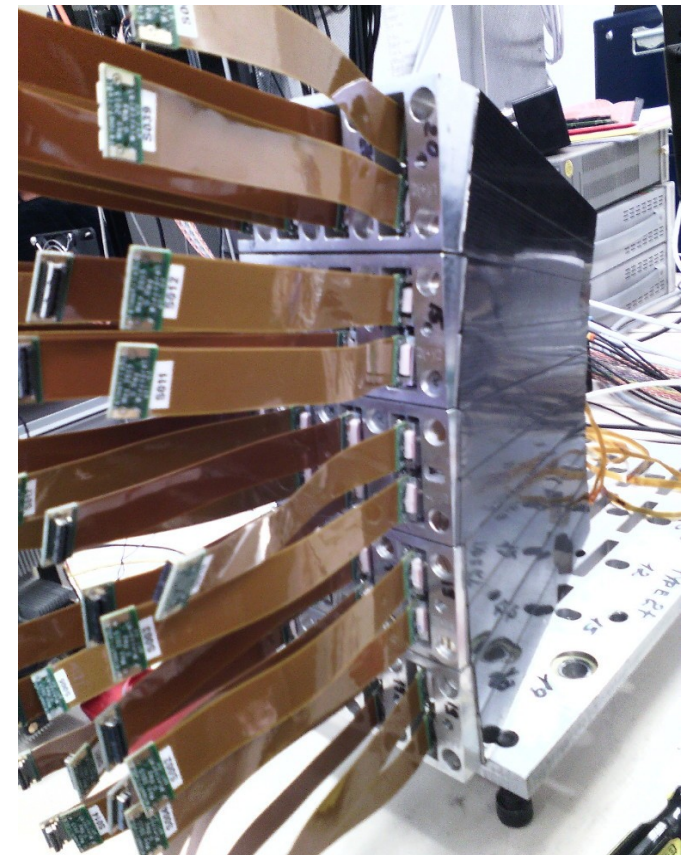
# Proto120



- Assembly of 2 crystal blocks (type 2 and 3)
- 80 crystals equipped with matched pairs of APDs based on information from APD database



- ASIC flex PCBs v6 with left- and right-hand connector configuration





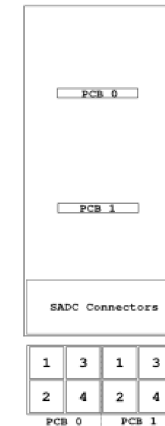
# Proto120

R A S P B E R R Y 1				R A S P B E R R Y 4				
C20 : 4 S037 A1, B1 366 5 <0> 364,86	C20 : 2 W040 A2, B2 368 5 <0> 362,90	C10 : 4 S030 A3, B3 353 60 5 <1> 362,73	C10 : 2 W043 A4, B4 379 1 5 <1> 344,33	A10 : 4 S007 A5, B5 324 2 10 <1> 369,69	A10 : 2 W054 A6, B6 317 3 10 <1> 345,94	A11 : 4 S008 A7, B7 176 4 10 <0> 345,21	A11 : 2 W001 A8, B8 321 5 10 <0> 370,13	
C20 : 3 S038 A9, B9 275 5 <0> 345,98	C20 : 1 W038 A10, B10 273 5 <0> 377,30	C10 : 3 S020 A11, B11 271 59 5 <1> 367,41	C10 : 1 W059 A12, B12 270 6 5 <1> 343,89	A10 : 3 S039 A13, B13 223 7 10 <1> 345,58	A10 : 1 W055 A14, B14 226 8 10 <1> 371,48	A11 : 3 S009 A15, B15 220 9 10 <0> 374,58	A11 : 1 W005 A16, B16 224 10 10 <0> 369,78	
C21 : 4 S032 A17, B17 360 4 <0> 362,59	C21 : 2 W036 A18, B18 370 4 <0> 362,16	C11 : 4 S031 A19, B19 367 58 4 <1> 365,03	C11 : 2 W042 A20, B20 364 11 4 <1> 345,73	A20 : 4 S012 A21, B21 332 12 9 <1> 345,10	A20 : 2 W020 A22, B22 333 13 9 <1> 344,60	A21 : 4 S019 A23, B23 315 14 9 <0> 344,52	A21 : 2 W004 A24, B24 335 15 9 <0> 344,80	
C21 : 3 S035 A25, B25 292 4 <0> 373,42	C21 : 1 W034 A26, B26 287 4 <0> 363,90	C11 : 3 S021 A27, B27 274 57 4 <1> 369,74	C11 : 1 W044 A28, B28 255 16 4 <1> 345,48	A20 : 3 S011 A29, B29 571 17 9 <1> 345,52	A20 : 1 W031 A30, B30 246 18 9 <1> 345,41	A21 : 3 S018 A31, B31 569 19 9 <0> 344,72	A21 : 1 W006 A32, B32 243 20 9 <0> 344,99	
F20 : 4 S034 A33, B33 381 3 <0> 347,75	F20 : 2 W030 A34, B34 352 3 <0> 367,10	F21 : 4 S022 A35, B35 375 56 3 <1> 366,69	F21 : 2 W041 A36, B36 390 21 3 <1> 344,94	F21 : 4 S010 A37, B37 331 22 8 <1> 369,47	F21 : 2 W058 A38, B38 316 23 8 <1> 358,20	F20 : 4 S017 A39, B39 216 24 8 <0> 345,67	F20 : 2 W002 A40, B40 177 25 8 <0> 368,25	
F20 : 3 S047 A41, B41 261 3 <0> 367,03	F20 : 1 W035 A42, B42 289 3 <0> 368,40	F21 : 3 S029 A43, B43 259 LED 55 3 <1> 350,29	F21 : 1 W047 A44, B44 280 26 3 <1> 375,72	F21 : 3 S003* A45, B45 250 27 8 <1> 363,17	F21 : 1 W032 A46, B46 570 28 8 <1> 363,46	F20 : 3 S043 A47, B47 252 29 8 <0> 373,28	F20 : 1 W063 A48, B48 237 30 8 <0> 361,03	
S046 A49, B49 371	W039 A50, B50 382	F11 : 4 S028 A51, B51 386 LED 54 2 <1> 367,71	F11 : 2 W045 A52, B52 363 31 2 <1> 355,20	F11 : 1 S0002 A53, B53 323 32 7 <1> 360,20	F11 : 3 W060 A54, B54 349 33 7 <1> 356,68	F10 : 1 S005* A55, B55 341 34 7 <0> 357,80	F10 : 3 W062 A56, B56 327 35 7 <0> 354,14	
S045 A57, B57 291	W038 A58, B58 285	F11 : 3 S023 A59, B59 254 LED 53 2 <1> 374,72	F11 : 1 W046 A60, B60 278 36 2 <1> 366,33	F11 : 2 S004 A61, B61 234 37 7 <1> 361,77	F11 : 4 W052 A62, B62 238 38 7 <1> 361,21	F10 : 2 S042 A63, B63 248 39 7 <0> 373,22	F10 : 4 W003 A64, B64 247 40 7 <0> 366,37	
A21 : 4 S044 A65, B65 355 1 <0> 376,68	A21 : 2 W029 A66, B66 378 1 <0> 367,22	A20 : 4 S025 A67, B67 362 LED 52 1 <1> 364,10	A20 : 2 W050 A68, B68 369 41 1 <1> 364,05	C20 : 1 S006 A69, B69 325 42 6 <1> 374,32	C20 : 3 W053 A70, B70 343 43 6 <1> 353,77	C21 : 1 S014 A71, B71 322 44 6 <0> 364,43	C21 : 3 W061 A72, B72 337 45 6 <0> 370,67	
A21 : 3 S036 A73, B73 258 1 <0> 377,96	A21 : 1 W033 A74, B74 266	A20 : 3 S026 A75, B75 262 LED 51 1 <1> 374,12	A20 : 1 W048 A76, B76 256 46 1 <1> 345,89	C20 : 2 S013 A77, B77 232 47 6 <1> 374,49	C20 : 4 W057 A78, B78 218 48 6 <1> 360,90	C21 : 2 S024 A79, B79 251 49 6 <0> 371,30	C21 : 4 W064 A80, B80 241 50 6 <0> 359,39	
top	T	Y	P	E	3	bottom	2	bottom

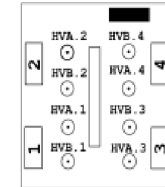
Backpl. : Link ASIC  
HV cable A, B  
**Crystal**  
Signal cable  
Buff.-Board <PCB> APD

- Depolished crystals
- Polished crystals
- Crystals + blue led

Buffer board:



Backplane:



GEO:

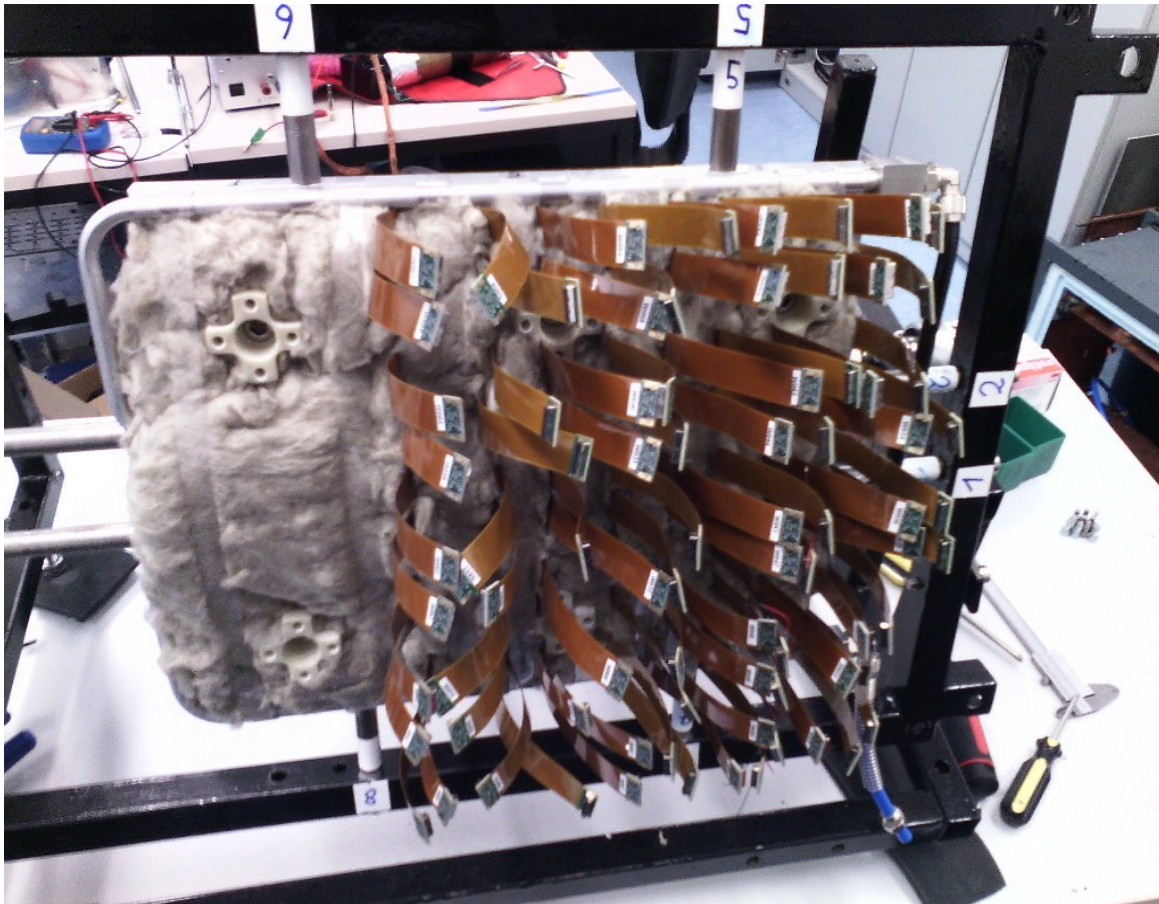
Orange	4
Green	3
Blue	2
Brown	1

Board ID  
(green 0 and red 1)  
**FEE-ID: 000-0-0110**  
Cable ID Geo



# Proto120

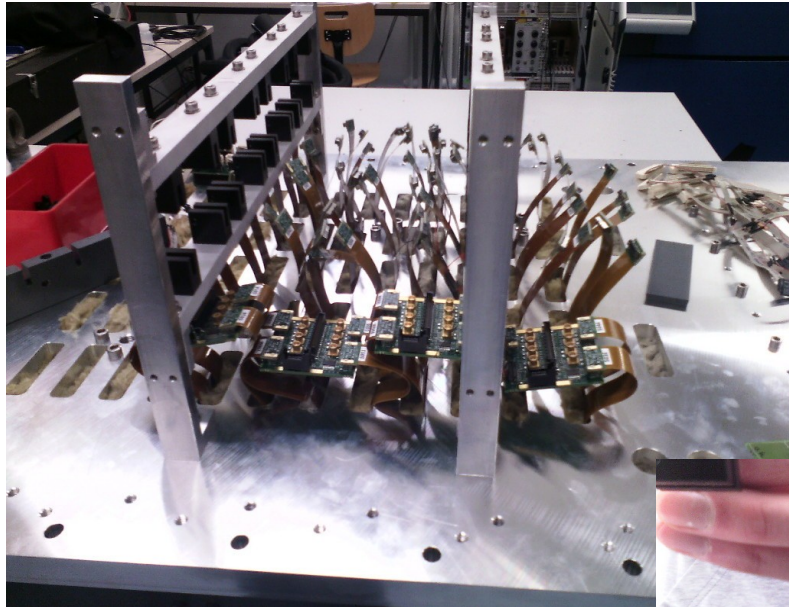
- new design of cooling plate, spacers and intermediate plate
- feed-through of ASIC cables into the warm part – now unproblematic



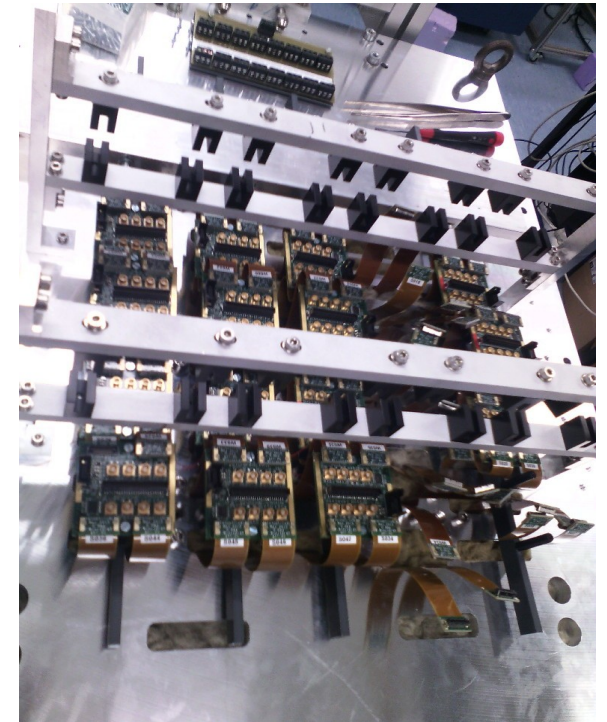
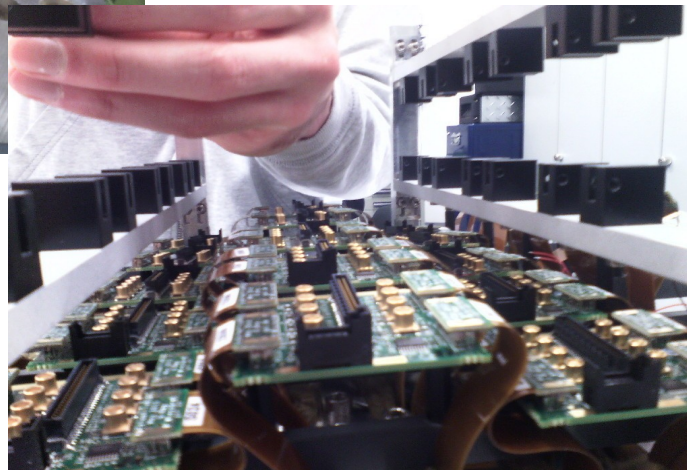


# Proto120

- ASIC cables still relatively stiff – problematic dense packing of backplane PCBs

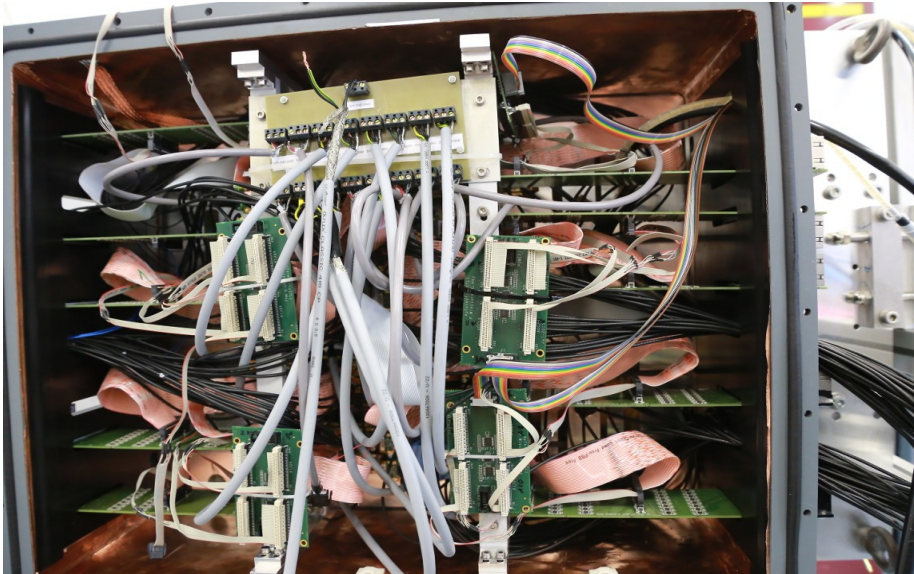


- solution: staggered configuration of BPL at two different heights



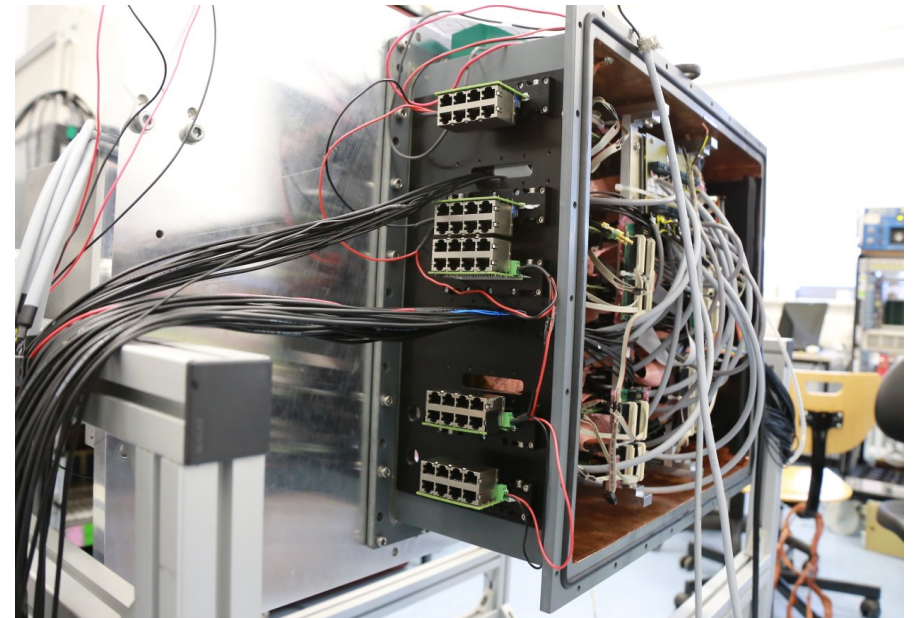
Ok for Proto120. But not for slice design due to limited clearance to inner edge of magnet

# Proto120



- integration of remaining electronics critical: several faulty connections due to dense cabling
- contact problems mainly in ribbon cables for signals but also in new cable scheme for ASIC slow control

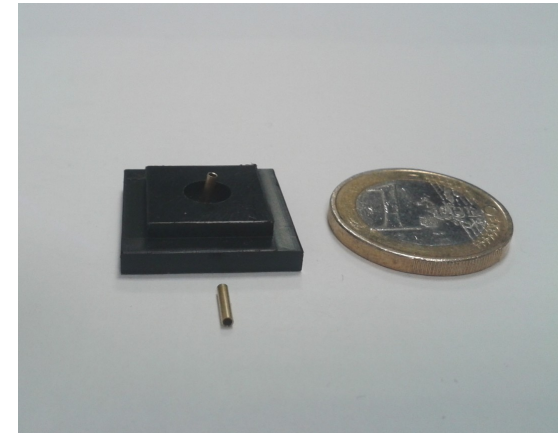
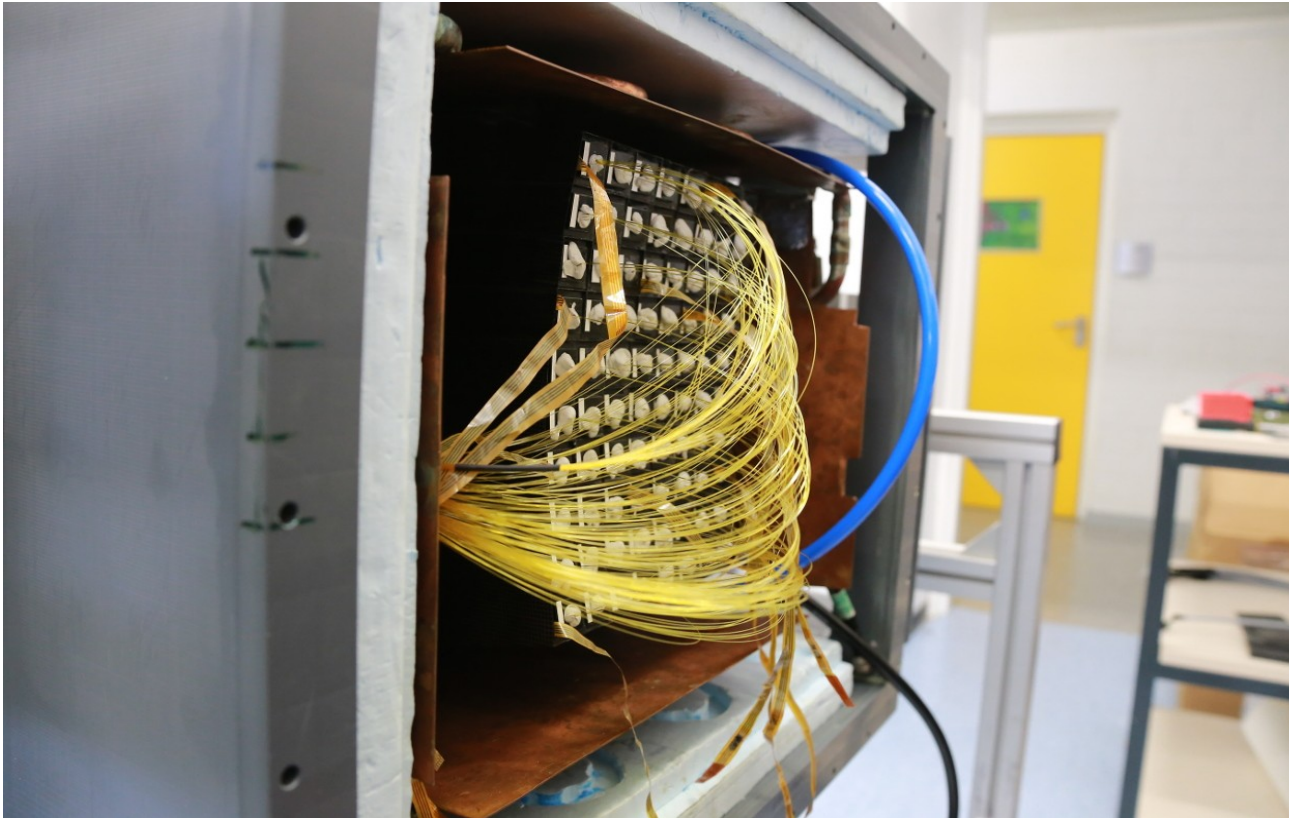
■ conclusion: re- and new design of entire electronics from BPL PCB on (including HV distribution)





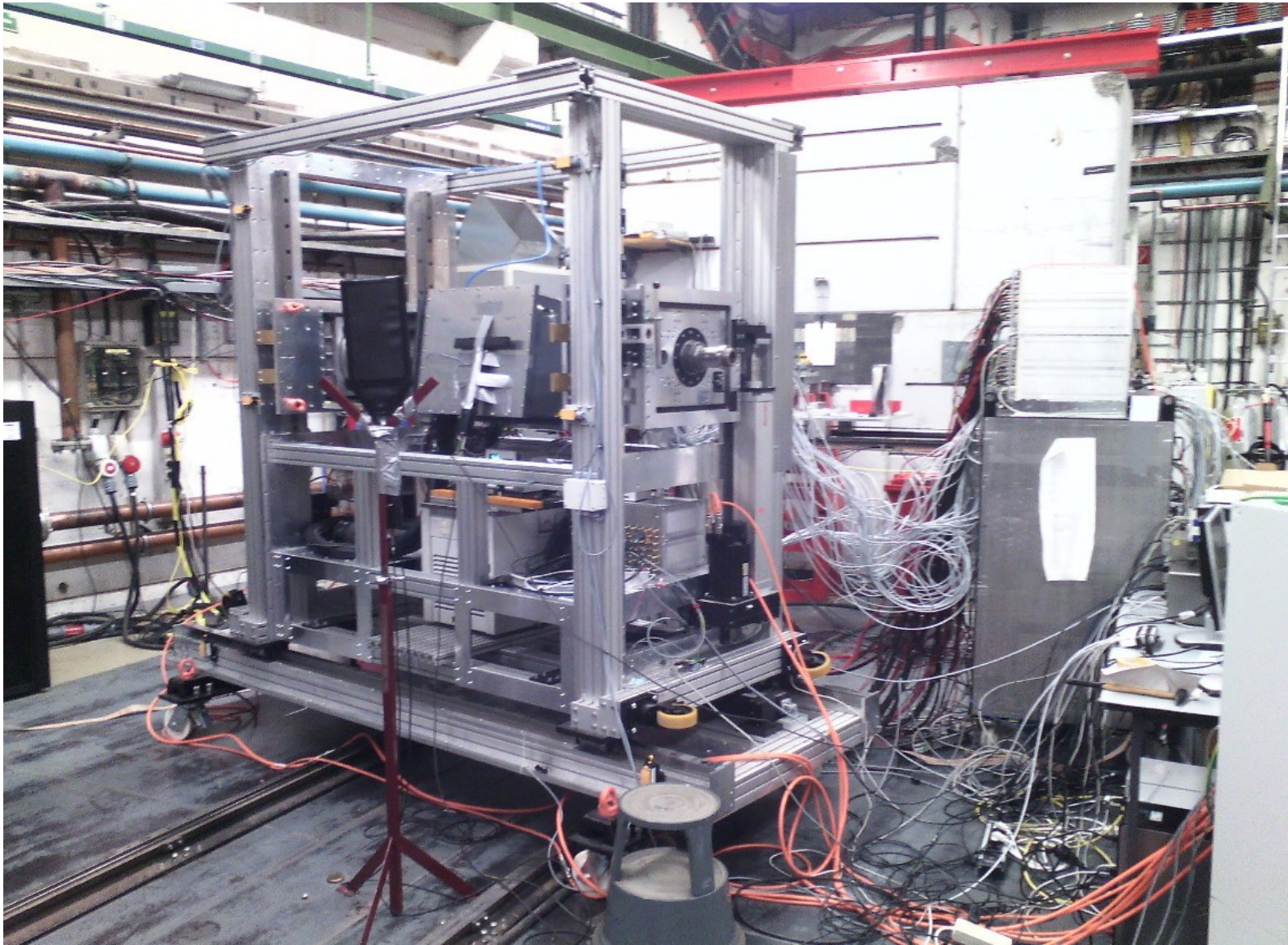
# Proto120

- all crystals equipped with monitoring light fibers fed into the crystal by a new (but not final) front stopper



Data taking with pulser performed – Analysis not started yet

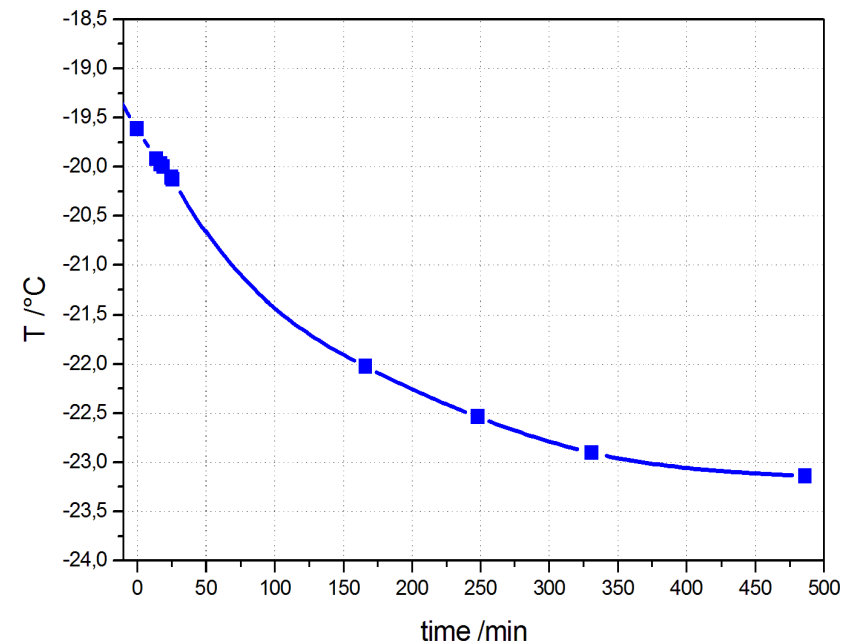
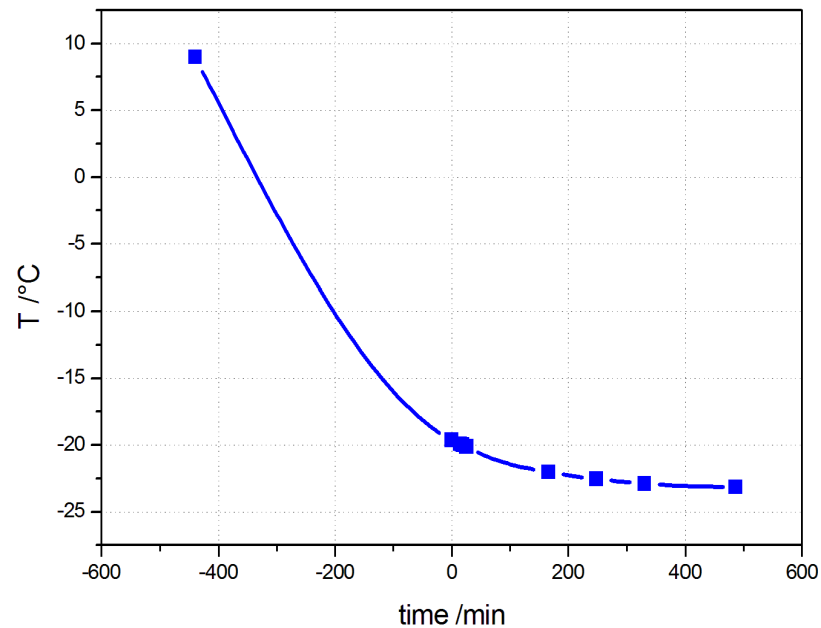
# Proto120





# Observations

- Cooling down to  $-25\text{ }^{\circ}\text{C}$  took longer than in previous tests ( $\sim 18\text{h}$  vs  $12\text{h}$ )

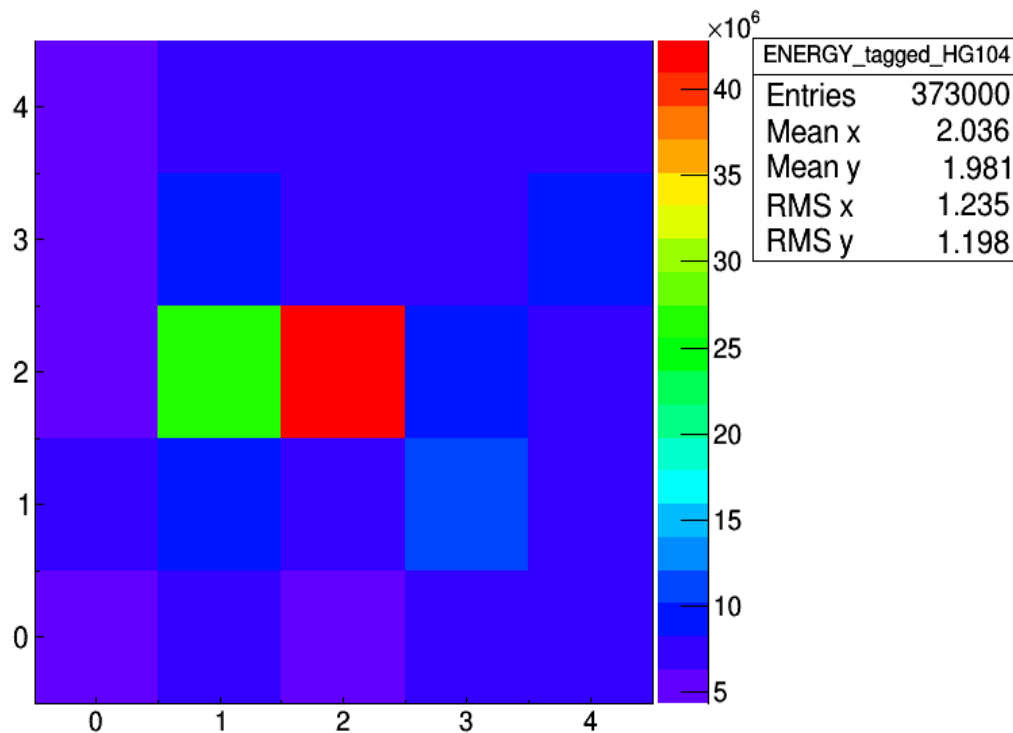


→ improve thermal Insulation (not under focus for this beam test)

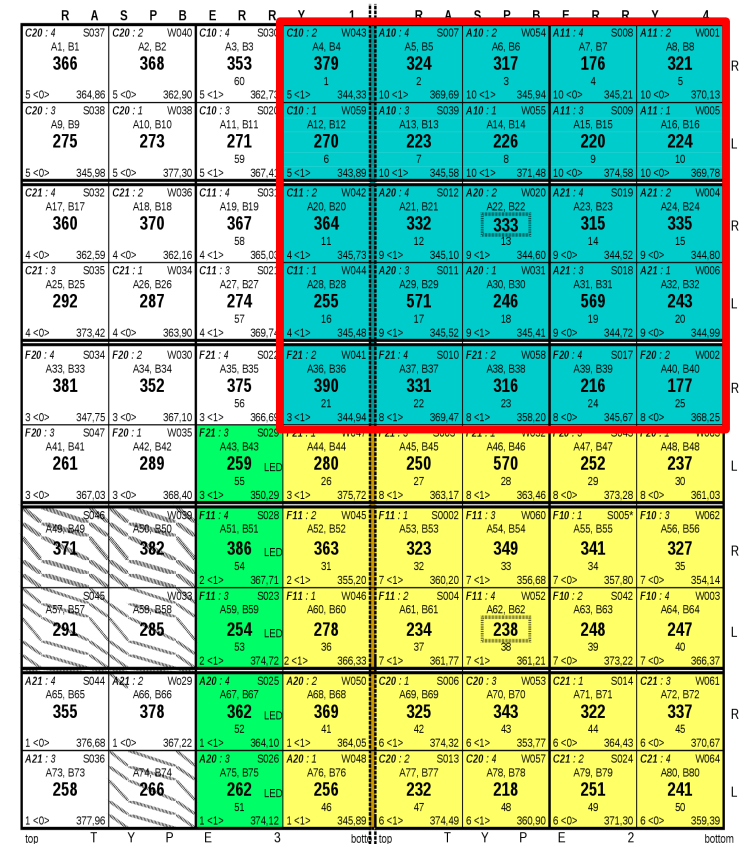


# Data Analysis

- Started analysis of data set for depolished crystal matrix
- Detector was aligned to incorporate beam into the central crystal exclusively



Mean deposited energy in 5x5 matrix during one run (a.u.)



# Data Analysis

- Simple peaking algorithm with adaptive base line
- For each channel and event extract mean(BL) and RMS(BL)
- Define pulse amplitude =  $\text{Max} ( \text{bl-min}, \text{max-bl} )$

