ECAL laser power scan

- Why is it important?
- Results
- Implications for Run 3

Dave Cockerill, ECAL laser power scans
Zurich, 23 June 2019

Why is the laser scan important?

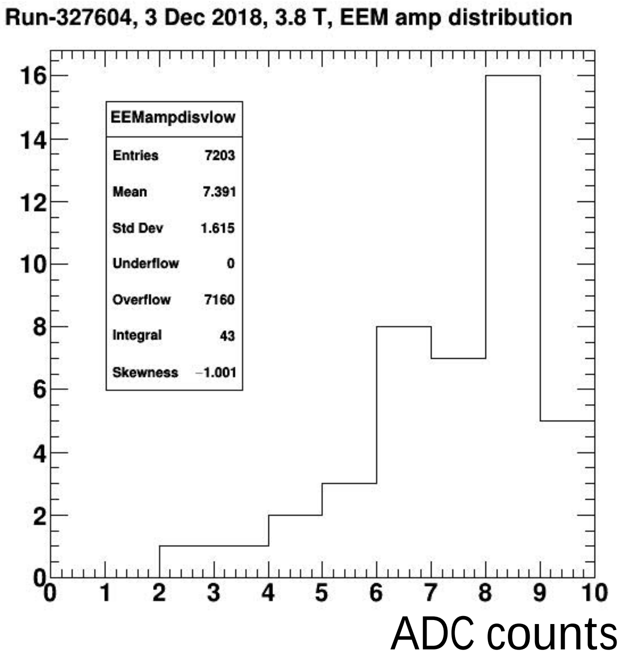
Expect a factor 25 further loss of laser signal at high eta by 450 fb^{-1}

Use the laser power scan to alert us to possible issues during Run 3 running.

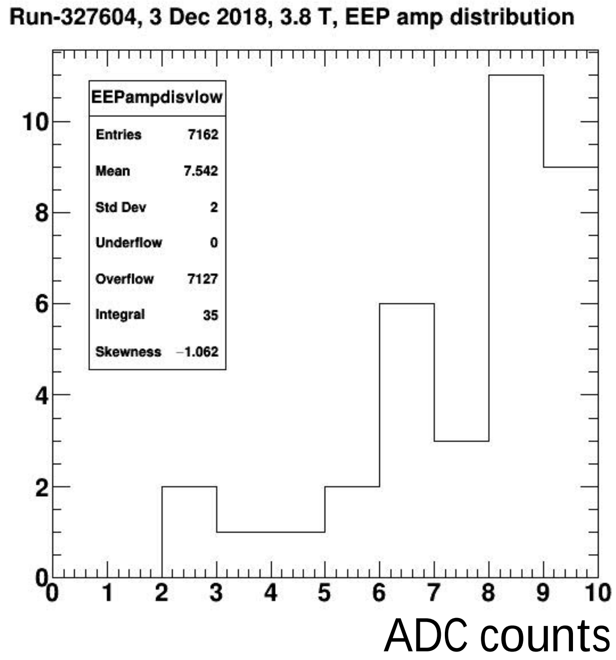
3 Dec 2018, miniDAQ, last run at 3.8 T : 327604

Laser DCC amplitudes < 10 ADC counts, in EEM and EEP

(standard laser power setting, good channels only)



EEM, 43 channels with < 10 ADC counts



EEP, 35 channels with < 10 ADC counts

ALL of these data will be less than 0.4 ADC counts by the end of Run 3

What can we do to manage this situation?

Laser power scans, 14 March 2019

Thanks to David Bailleux, David Valsecchi, Giacomo Cucciati, Thomas Reis, Franceso Pandolfi, and Tanmay Mudholkar

B = 0 T, miniDAQ data

Higher laser power settings		Lower laser power settings (pns at gain 16 only)
1	pn G16 and G1	0.778
1.375	pn G16 and G1	0.583
2	pn G16 and G1	0.417
3.889	pn G1*	0.194
4.51	pn G1*	0.097
		1

* Except EEM lower quadrant that remained with pn gain 16

Giacomo’s Laser power scan details/runs

Data

All laser scan miniDAQ runs processed to provide DQM data.

The DQM data provide a very convenient format to look at the base laser data

Extracted 3 main items for each EE channel:

DCC laser amplitude	in ADC counts
DCC/pn	
from which:	
pn	in ADC counts

For each laser run in Run 3, it would be very useful to have these data on EOS

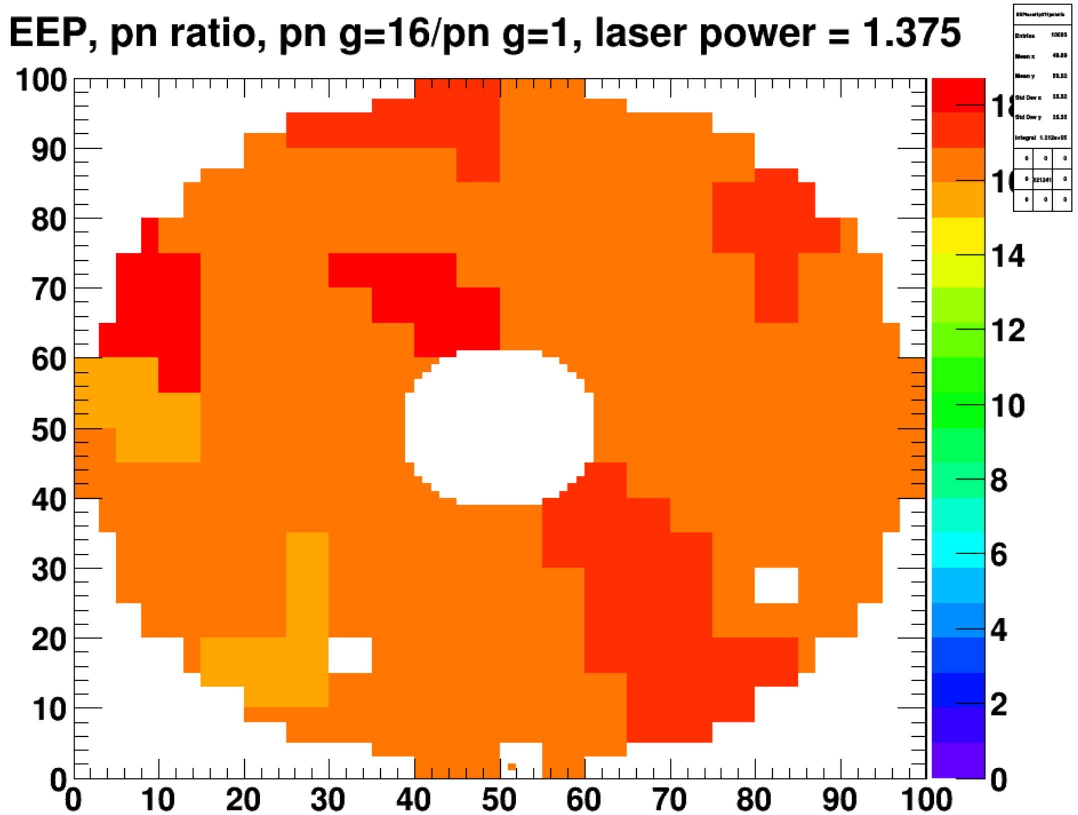
They are the direct, unprocessed, output from the detector, and provide useful feedback concerning the state of the channels

Example of two runs at pn gain = 16 and at pn gain =1, EEP
Relative laser power 1.375

Take ratio of pn signal, gain 16, to pn signal, gain 1

Ratios from ~15-18, as expected

Clear pn regions visible – a useful check



EEP

Laser power scans, 14 March 2019

miniDAQ Data Summary

16 runs from 328335 – 328362

2 issues:

First miniDAQ run: 328335

No laser signals in first events. MiniDAQ averages affected (thanks Yvgeni Vlassov)

Check delay for switching laser and the start of a laser run with miniDAQ??

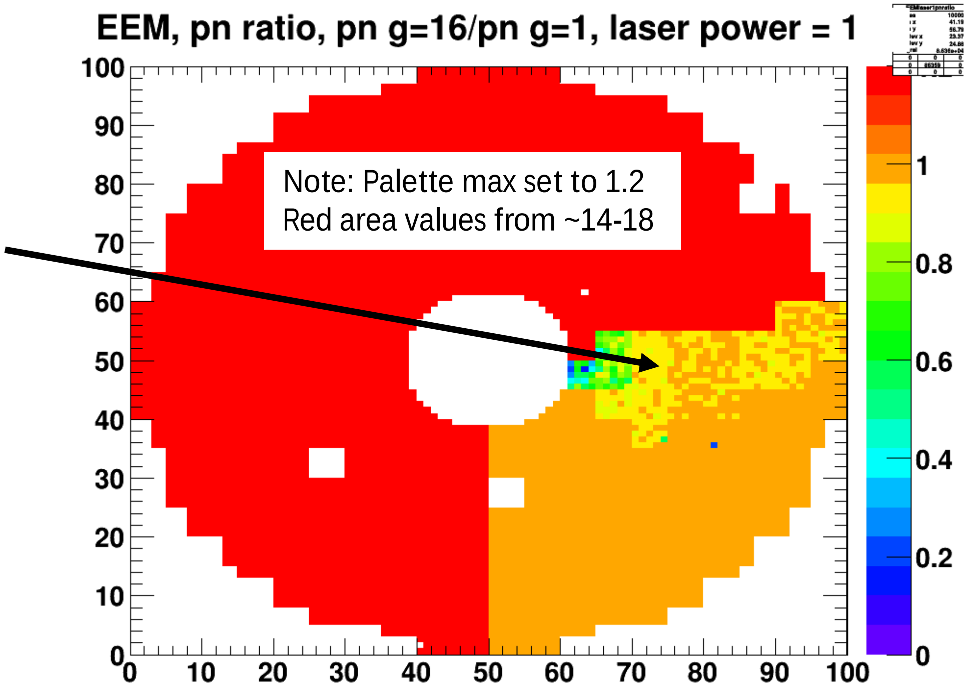
For all the laser power scan runs:

EEM-07, -06, -05 (D4-far)

pn gain remained at 16 throughout.

Switching to gain 1 not possible.

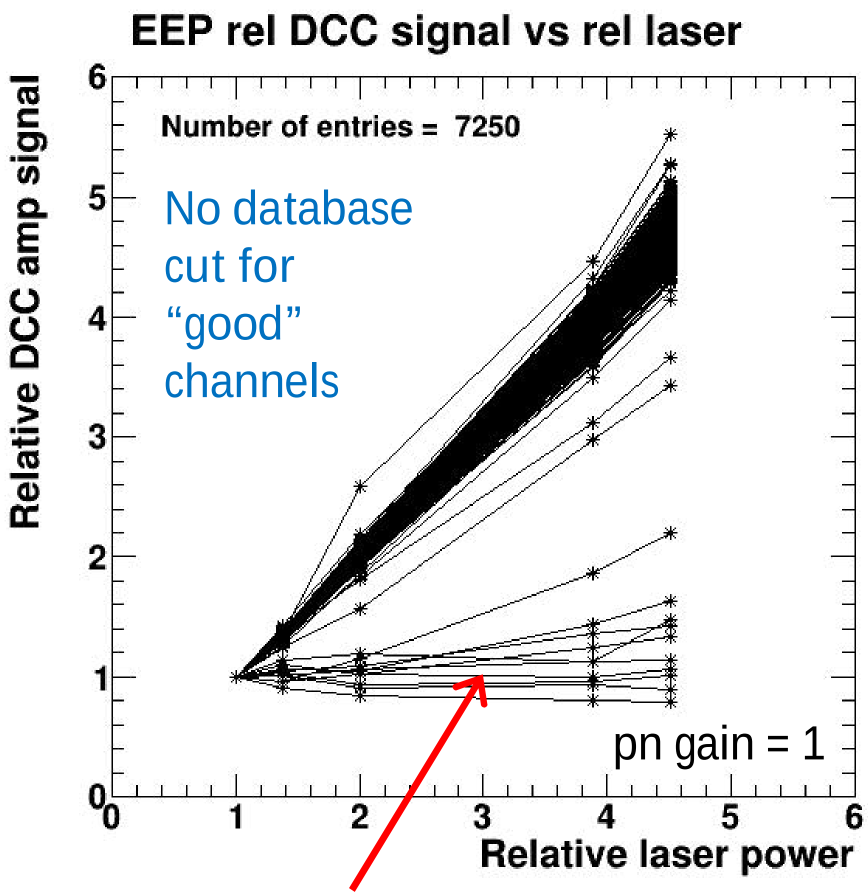
Run 328335 (gain 16) / 328338 (gain 1)



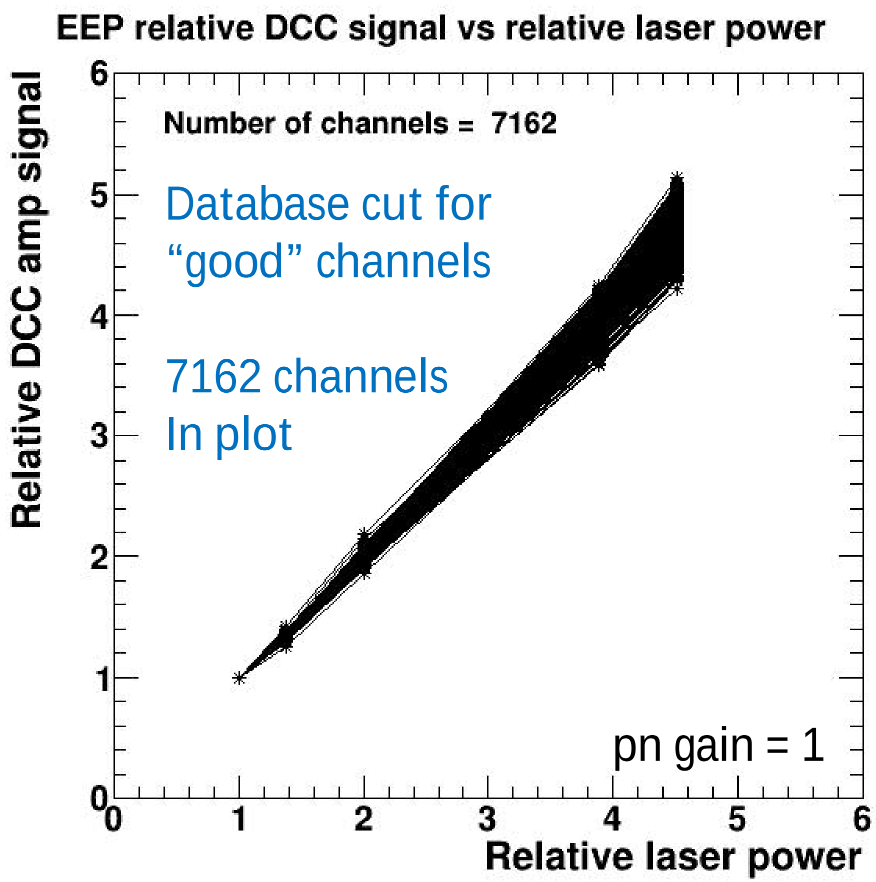
EEM

However, can very usefully exploit the EEM lower quadrant data to appraise pn at higher laser powers.

EEP, Relative DCC ADC amplitudes vs relative laser power



No increase in response for these bad channels, wrt laser power

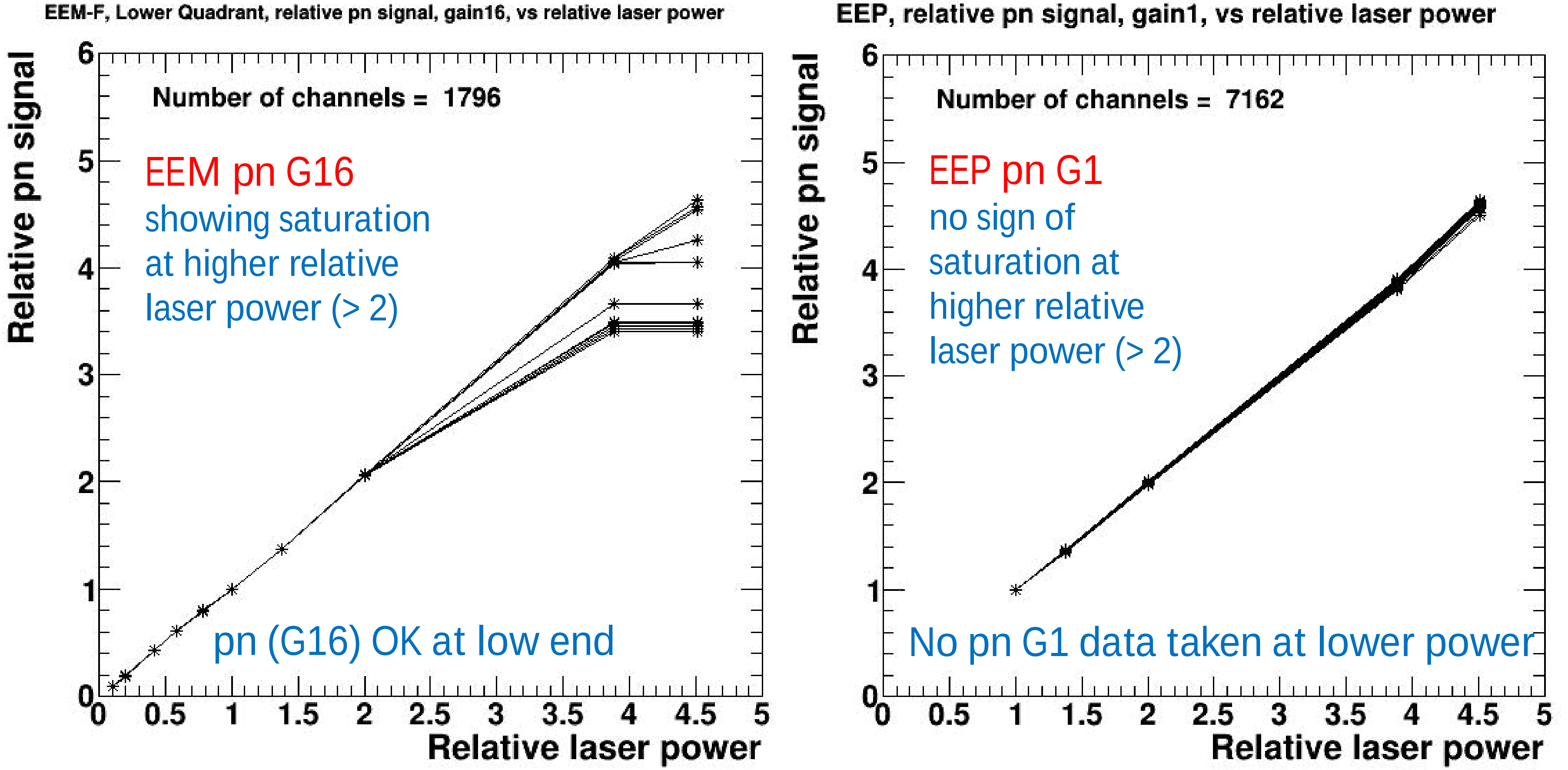


Only "good" channels from the database The plot is "clean"

Linear relationship between relative laser power and relative DCC amplitude (for relative laser power of unity and above).

A verification of the bad channel allocations in the ECAL database.

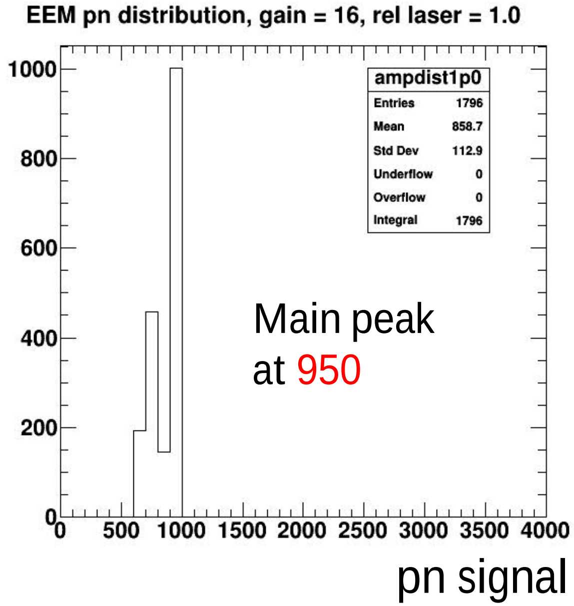
EEM LQ, relative pn amplitude, G16 and EEP G1, vs relative laser power



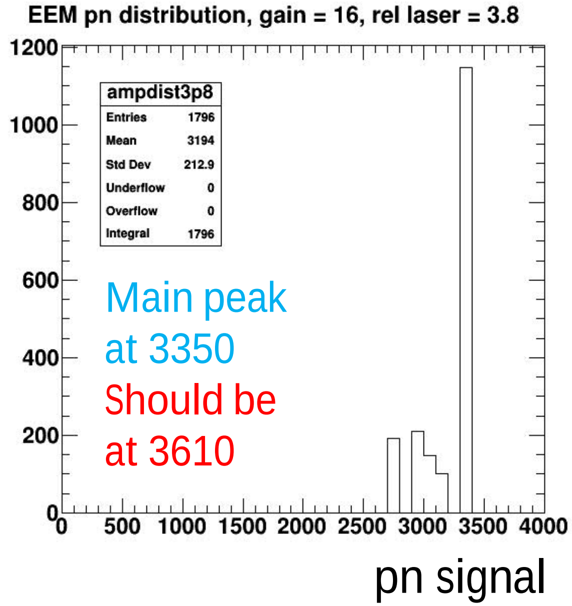
- pn amplitude, G16, saturating above a relative laser power of 2 in many regions
- pn amplitude, G1, no pn saturation, with respect to laser power

The pn amplitude distributions from EEM, G16

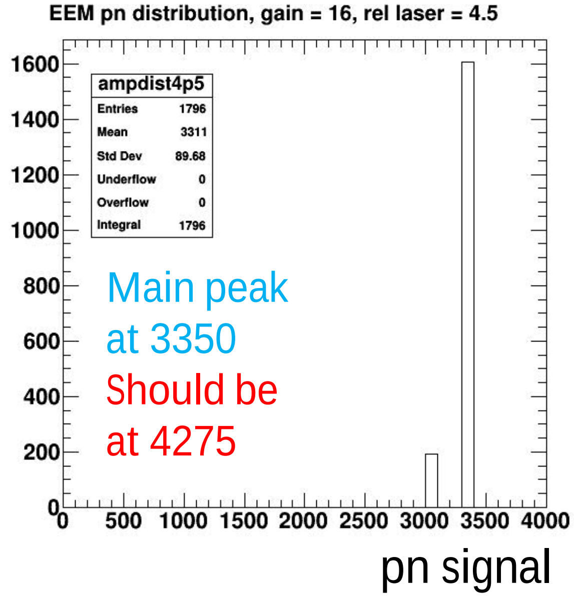
Laser power = 1.0



Laser power = 3.8



Laser power = 4.5



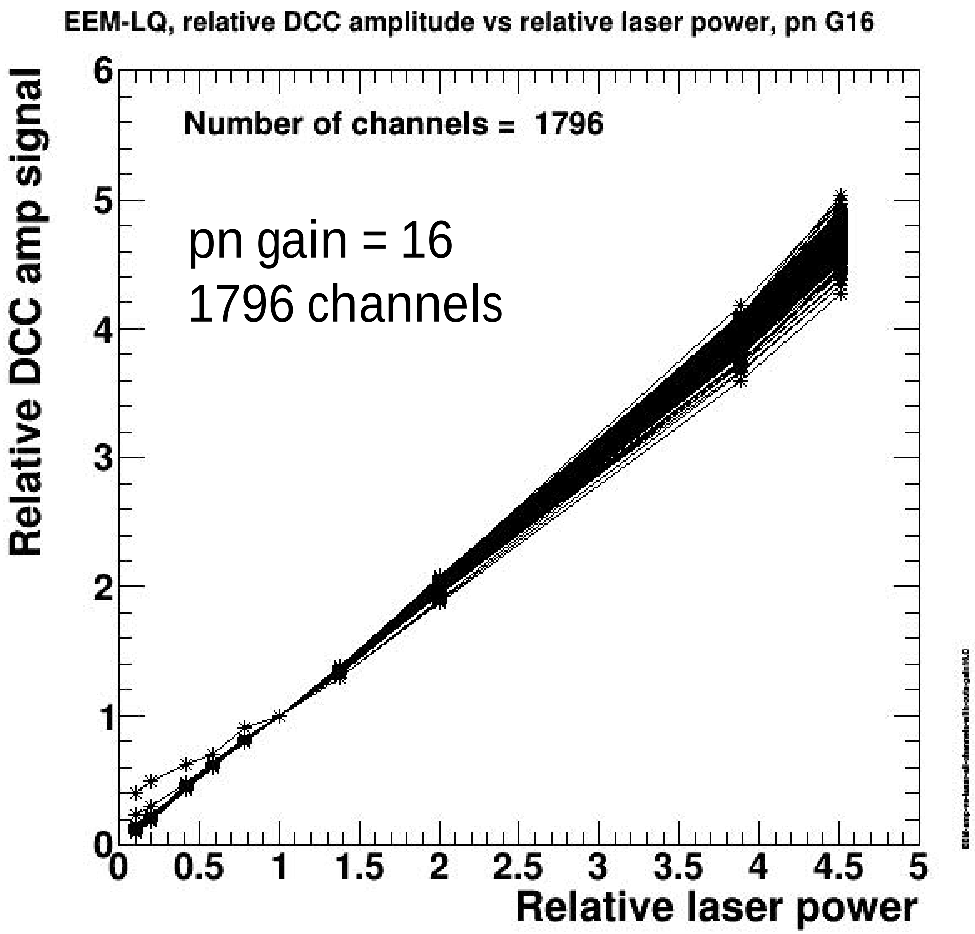
Data piling up at 3350 ADC counts

pn saturation at laser power factors of 3.8 and 4.5, for pn gain 16

- No data beyond 3350 ADC counts
- saturation of the pn preamp or MEM ADC or both ?

- Pedestal, 4096 – 3350 = 746 ADC counts
- pedestal could be reduced to ~100 ADC counts to give more dynamic range, if this is the problem

The relative DCC amplitude vs relative laser power
EEM lower quadrant



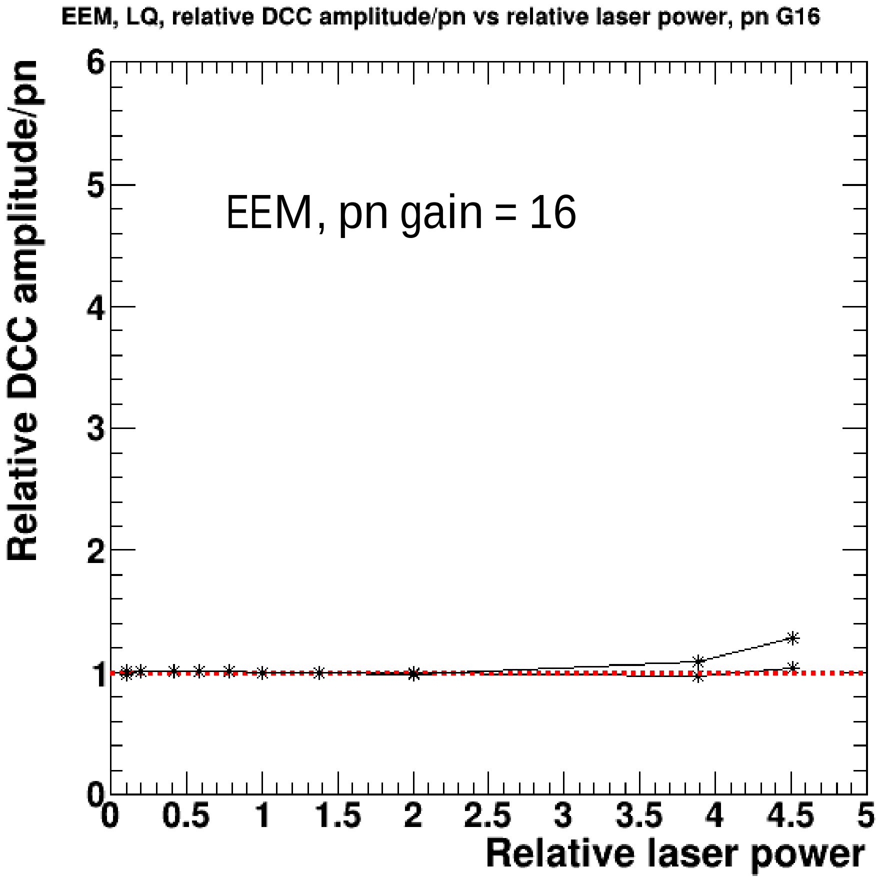
DCC amplitudes: no apparent saturation with respect to laser power, but will see issues at lower DCC amplitudes on the next slides

The “Relative DCC amplitude/pn” or “Double ratio”

DCC/pn divided by
(DCC/pn, relative laser power = 1)

$$= \frac{DCC}{pn} * \frac{pn_{\text{rel laser power = 1}}}{DCC_{\text{rel laser power = 1}}}$$

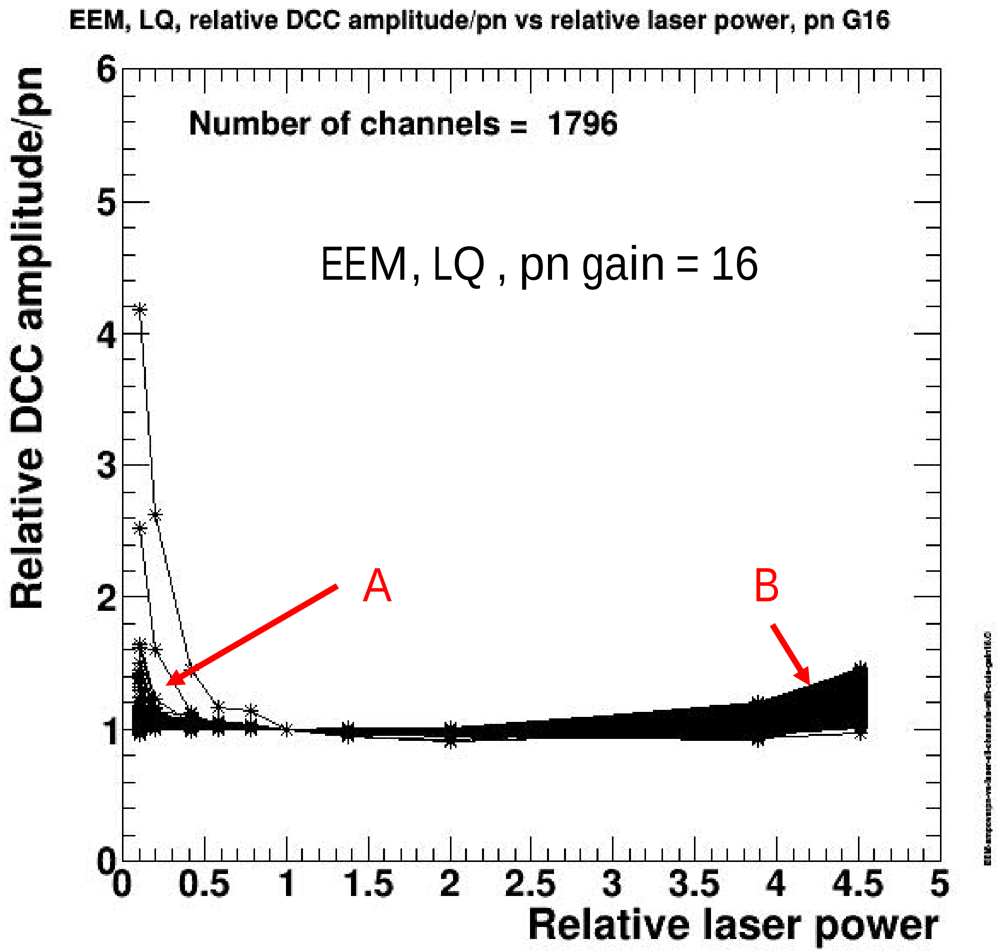
- for 2 channels
- the double ratio calculated for each laser setting
- The DCC/pn signal should correctly normalize the size of the laser pulse at all laser power settings
- The double ratio should be unity at all laser power settings.



- The double ratio is unity up to relative laser power = 2
- See evidence of pn saturation for relative laser power > 2.0

The “Double ratio” or Relative DCC amplitude/pn

- for 1796 EEM lower quadrant channels, pn gain = 6
- Double ratio calculated at each laser setting
- There are deviations from unity at A and B

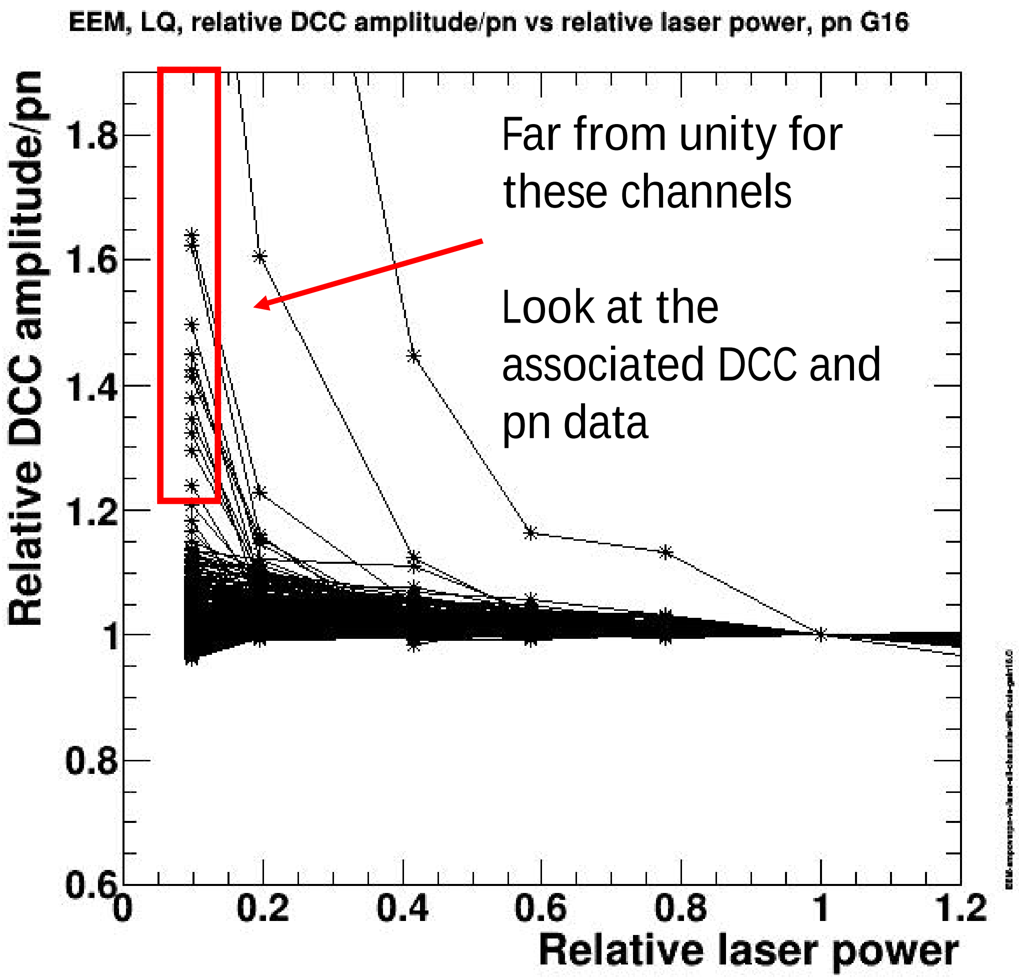


- Data at “A”: DCC amplitudes too large – see next slides
- Data at “B”: pn data saturation, for pn gain = 16, for relative laser power settings > 2

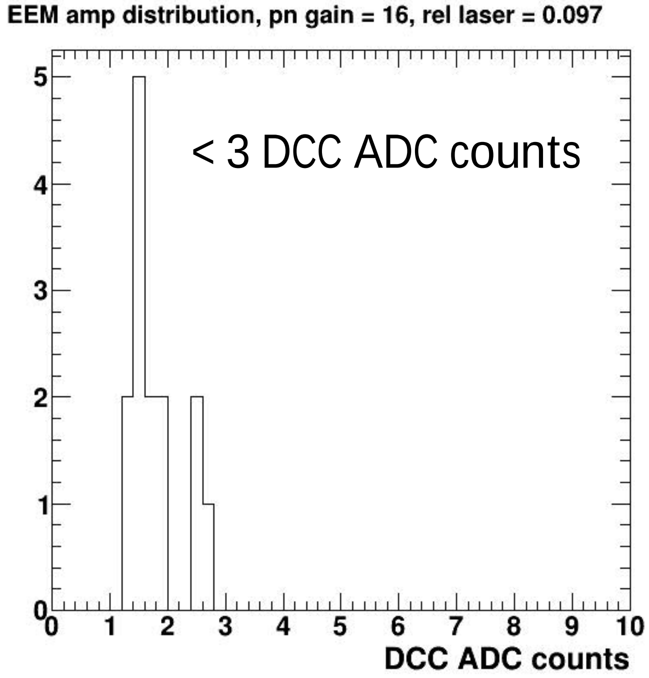
EEM, the Double ratio

Zoom-in to the double ratio data at lower laser power settings

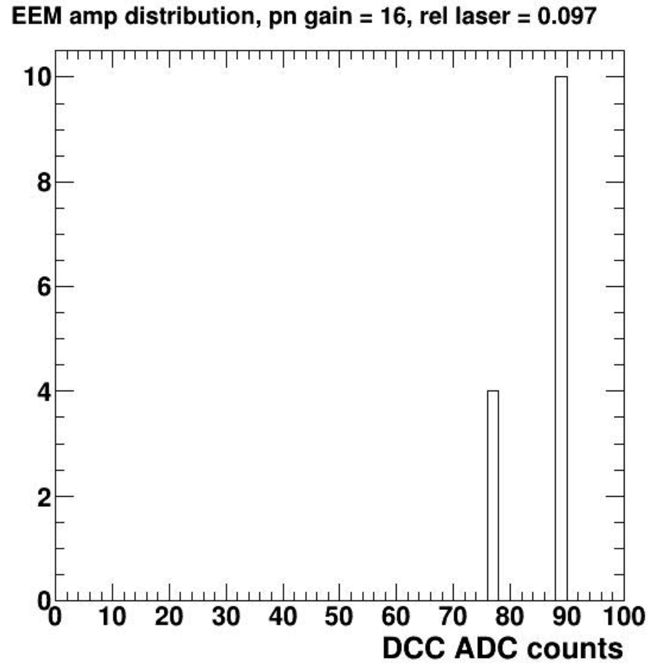
- Many channels not at unity
- Look at the associated DCC and pn data



Channels with a double ratio > 1.2, at a laser power of 0.097, EEM LQ



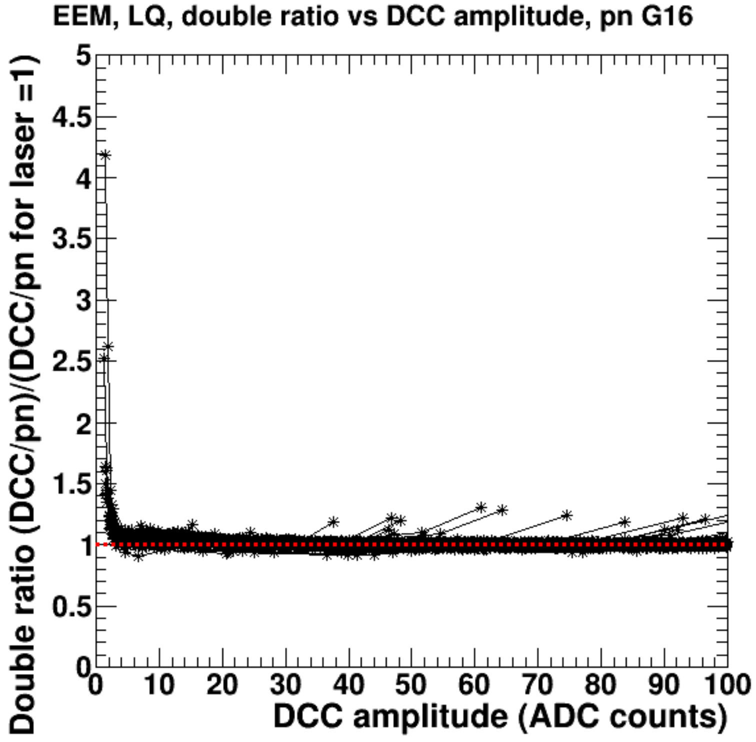
Laser amplitudes

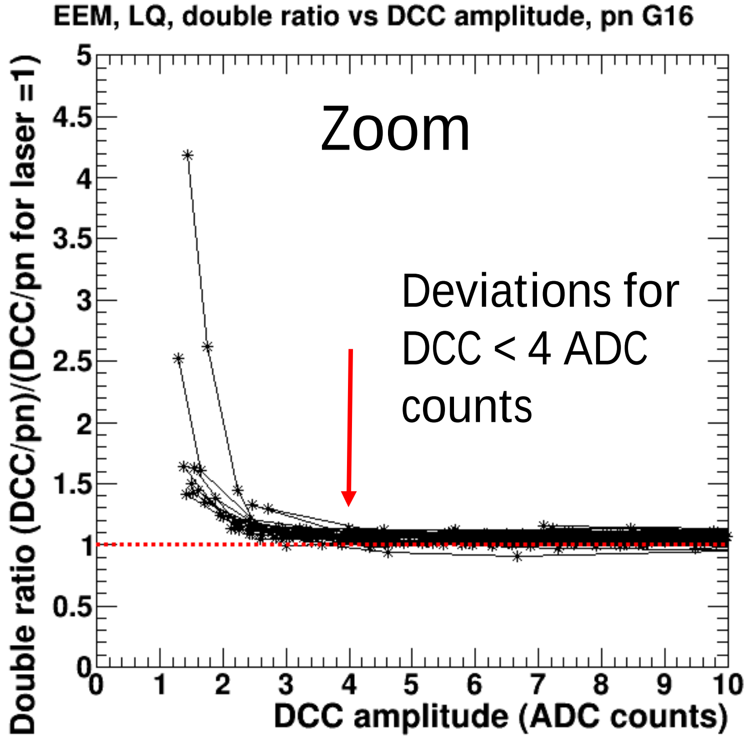


Reasonable pn signals of 77 – 88 ADC counts

- Low DCC signals (< 3 ADC counts) associated with the double ratio values > 1.2, but reasonable pn values
- The issue is with the measured DCC amplitudes

The double ratio as a function of DCC amplitude, EEM LQ

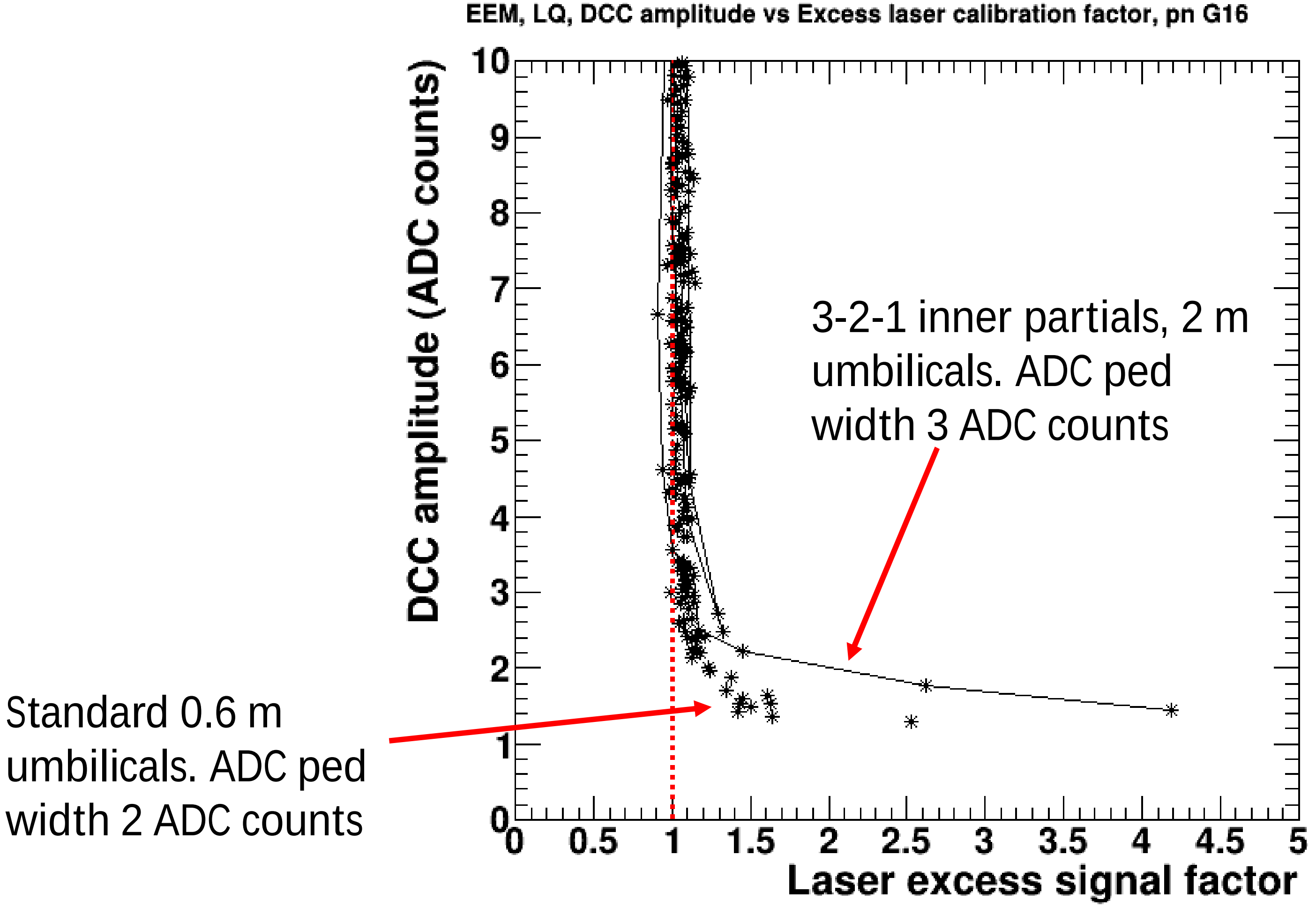




- The double ratio deviates significantly from unity for DCC amplitudes < 4 ADC counts
- Laser calibration signals in excess by factors of up to 4.2 (420%).

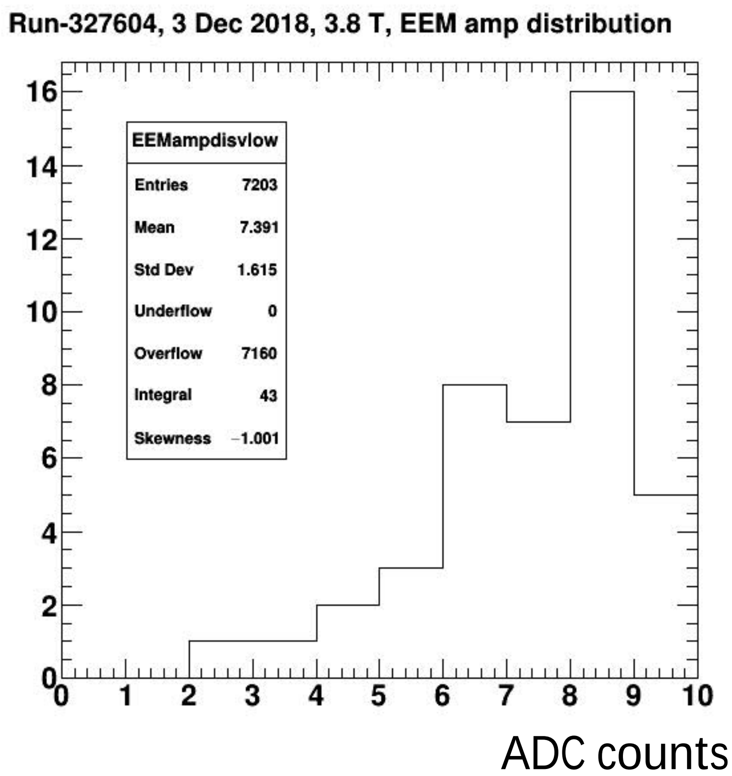
Suspect preamp non-linearity, or digitization errors with respect to the EE pedestal rms of 2-3 ADC counts, incorrectly leading to higher than expected DCC amplitudes

Excess laser signal wrt DCC amplitude (ADC counts), EEM LQ

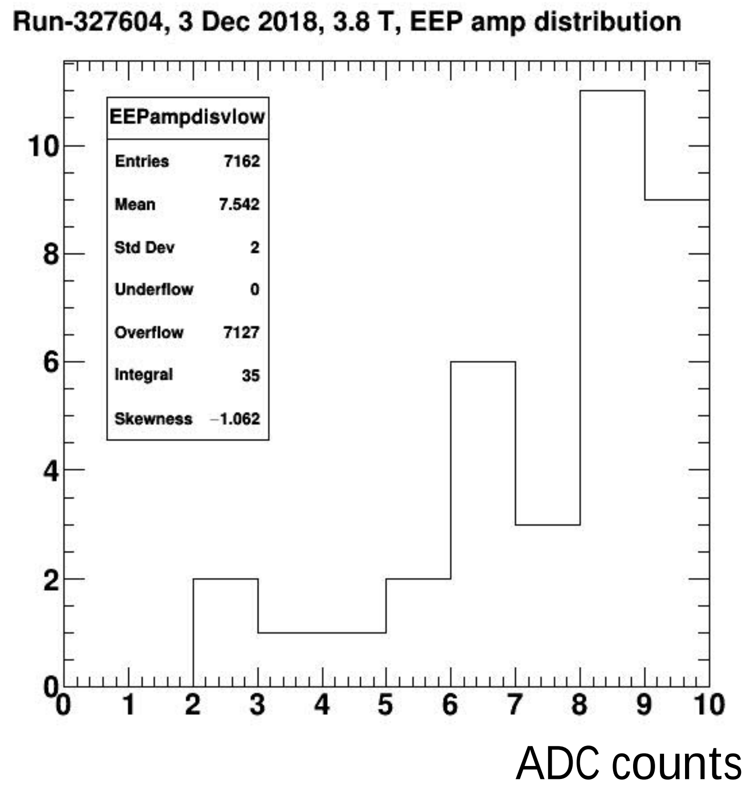


- Below 3-4 ADC counts, reconstructed laser signal is up to 4 times larger than it should be
- Particular trajectories for standard and inner (3-2-1) supercrystals
- To do: include data from the other 7 quadrants

Back to the DCC distributions for the current detector 3 Dec 2018 at 3.8 T



EEM, 43 channels with < 10 ADC counts



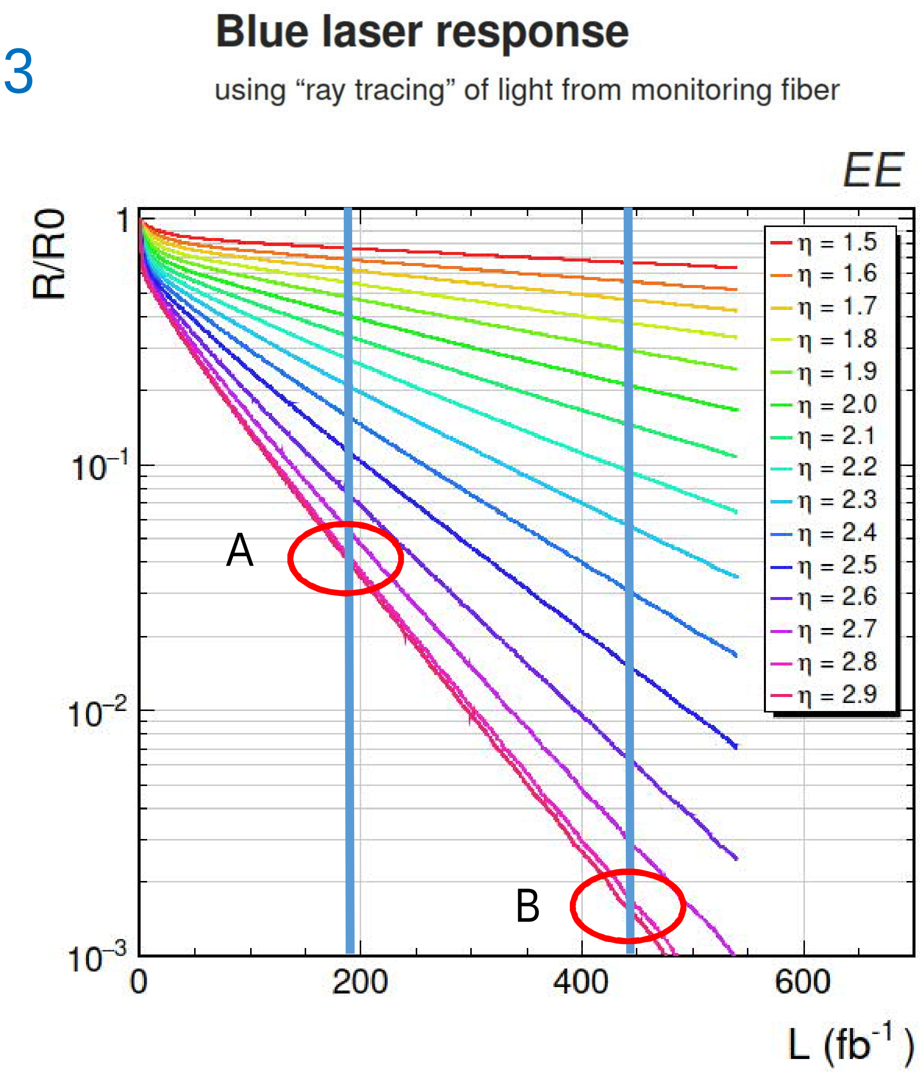
EEP, 35 channels with < 10 ADC counts

- See DCC amplitudes as low as 2.1 and 2.3 ADC counts
- Already need to consider running the laser at higher power, at the very start of Run 3, for reasonable DCC amplitudes for the inner EE region

Transparency model for Run 3
Alexander Ledovskoy
DPG, Sep 12, 2018

“A”: End Run 2, eta = 2.9
Relative Laser 4 . 10^{-2}

“B”: End Run 3, eta = 2.9
Relative Laser 1.6 . 10^{-3}



End Run 2 to End Run3
Further laser loss factors of ~25 at eta = 2.9

ADC meltdown

Lowest EE laser count, 3 Dec 2018	2.1 counts (3.8T, see backup)
With current laser, top power, factor 4.5	9.45 counts
Factor 25 further loss, end 2018 to end Run 3	0.38 counts
New laser, 10x more powerful	3.8 counts

- Timely to scan market to see what modern lasers can deliver
- Need >10 mJ per pulse (max current laser pulse is 1 mJ)
- Current lasers: 2011/2012. Technology 8 years old.

To note:

The inner EE channels are fully working.

The pulse shapes from the VPTs are correct – no sign of breakdown or other anomalous behavior.

Valid response to sufficiently high energy deposits.

The only challenge – establishing the correct calibration to properly include these data for physics.

Laser Power Scan – Conclusions

- Need higher laser power settings in Run 3 for EE
- Significant non-linearities observed for DCC amplitudes < 5 ADC counts

- pn saturation seen for relative laser power > 2
- Running with pn gain = 1 will be necessary
  - Need to fix the EEM lower quadrant problem
  - A possible task for the June/July 2019 runs
  - Store the base DCC and pn data on EOS for Run 3

- Laser signal – will lose a further factor of 25, inner region, end Run 3
- Current laser – can get to a relative power of 4.5
  - Does not adequately deal with the ageing
  - Would have laser signals of < 0.5 ADC counts

Timely to scan the market for a more powerful laser, factor >10 for reasonable calibration data to end Run 3 with most data > 5 - 10 ADC counts

Backup slides

3 Dec 2018, last run at 3.8 T (miniDAQ)
Laser DCC amplitudes < 5 ADC counts, in EEM and EEP

(standard laser power setting, good channels only)

EEM
===

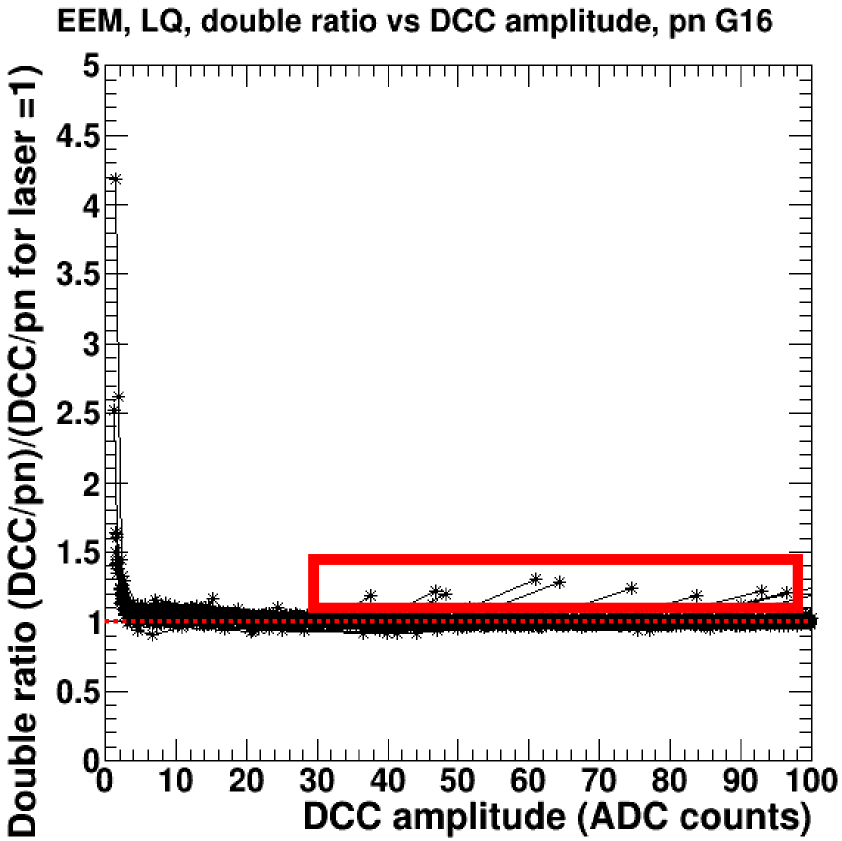
iz = 0, x = 39.5, y = 57.5, amp = 4.9
iz = 0, x = 39.5, y = 60.5, amp = 4.5
iz = 0, x = 57.5, y = 40.5, amp = 2.3 a 3-2-1 partial supercrystal
iz = 0, x = 63.5, y = 48.5, amp = 3.5

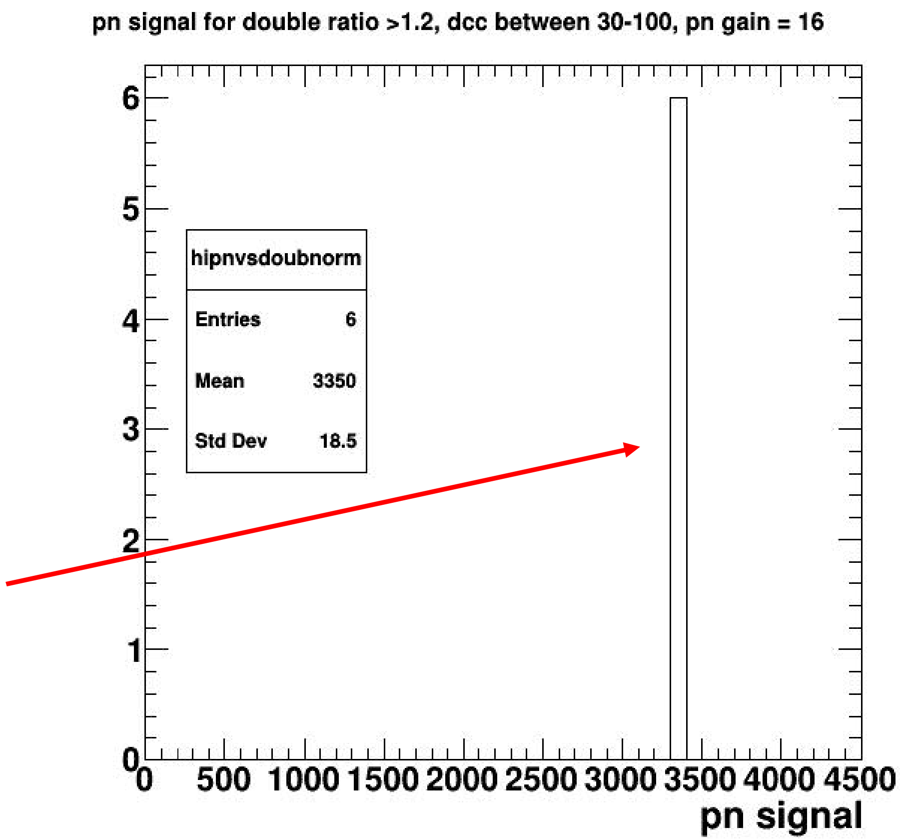
EEP
===

iz = 1, x = 38.5, y = 45.5, amp = 2.1
iz = 1, x = 38.5, y = 46.5, amp = 2.3
iz = 1, x = 55.5, y = 60.5, amp = 3.7
iz = 1, x = 62.5, y = 50.5, amp = 4.1

Note: cannot get laser DCC ADC counts from the eos file containing all laser data for 2018 – this only has the normalised laser correction factor, DCC/pn, and includes alpha.

Reason for high double ratios, > 1.2, at pn gain = 16





High double ratios, > 1.2:

pn saturation above relative laser power setting of 2.0 for some channels (amp/pn) / (amp, laser=1/pn, laser = 1)

amp = 1.70	pn = 89.59
amp = 1.87	pn = 89.63
amp = 1.52	pn = 88.68
amp = 1.37	pn = 88.51
amp = 1.96	pn = 88.64
amp = 1.44	pn = 88.54
amp = 2.72	pn = 88.62
amp = 2.47	pn = 88.56
amp = 2.43	pn = 88.63
amp = 1.42	pn = 88.56
amp = 1.54	pn = 76.54
amp = 1.50	pn = 76.53
amp = 1.60	pn = 76.51
amp = 1.29	pn = 76.54

doublenorm[0] > 1.2, x = 50.50, y = 38.50, ref1 = 0.01898, ampscan[0] = 0.01409, doublenorm[0] = 1.35, amp = 1.70, pn = 89.59
doublenorm[0] > 1.2, x = 51.50, y = 36.50, ref1 = 0.02083, ampscan[0] = 0.01508, doublenorm[0] = 1.38, amp = 1.87, pn = 89.63

doublenorm[0] > 1.2, x = 55.50, y = 35.50, ref1 = 0.01715, ampscan[0] = 0.01204, doublenorm[0] = 1.42, amp = 1.52, pn = 88.68
doublenorm[0] > 1.2, x = 55.50, y = 38.50, ref1 = 0.01543, ampscan[0] = 0.00941, doublenorm[0] = 1.64, amp = 1.37, pn = 88.51

doublenorm[0] > 1.2, x = 56.50, y = 36.50, ref1 = 0.02215, ampscan[0] = 0.01789, doublenorm[0] = 1.24, amp = 1.96, pn = 88.64
doublenorm[0] > 1.2, x = 57.50, y = 40.50, ref1 = 0.01624, ampscan[0] = 0.00388, doublenorm[0] = 4.19, amp = 1.44, pn = 88.54

doublenorm[0] > 1.2, x = 58.50, y = 40.50, ref1 = 0.03070, ampscan[0] = 0.02371, doublenorm[0] = 1.29, amp = 2.72, pn = 88.62
doublenorm[0] > 1.2, x = 59.50, y = 41.50, ref1 = 0.02789, ampscan[0] = 0.02106, doublenorm[0] = 1.32, amp = 2.47, pn = 88.56

doublenorm[0] > 1.2, x = 60.50, y = 40.50, ref1 = 0.02736, ampscan[0] = 0.02267, doublenorm[0] = 1.21, amp = 2.43, pn = 88.63
doublenorm[0] > 1.2, x = 60.50, y = 42.50, ref1 = 0.01608, ampscan[0] = 0.01137, doublenorm[0] = 1.41, amp = 1.42, pn = 88.56

doublenorm[0] > 1.2, x = 61.50, y = 47.50, ref1 = 0.02014, ampscan[0] = 0.01240, doublenorm[0] = 1.62, amp = 1.54, pn = 76.54
doublenorm[0] > 1.2, x = 61.50, y = 48.50, ref1 = 0.01956, ampscan[0] = 0.01306, doublenorm[0] = 1.50, amp = 1.50, pn = 76.53

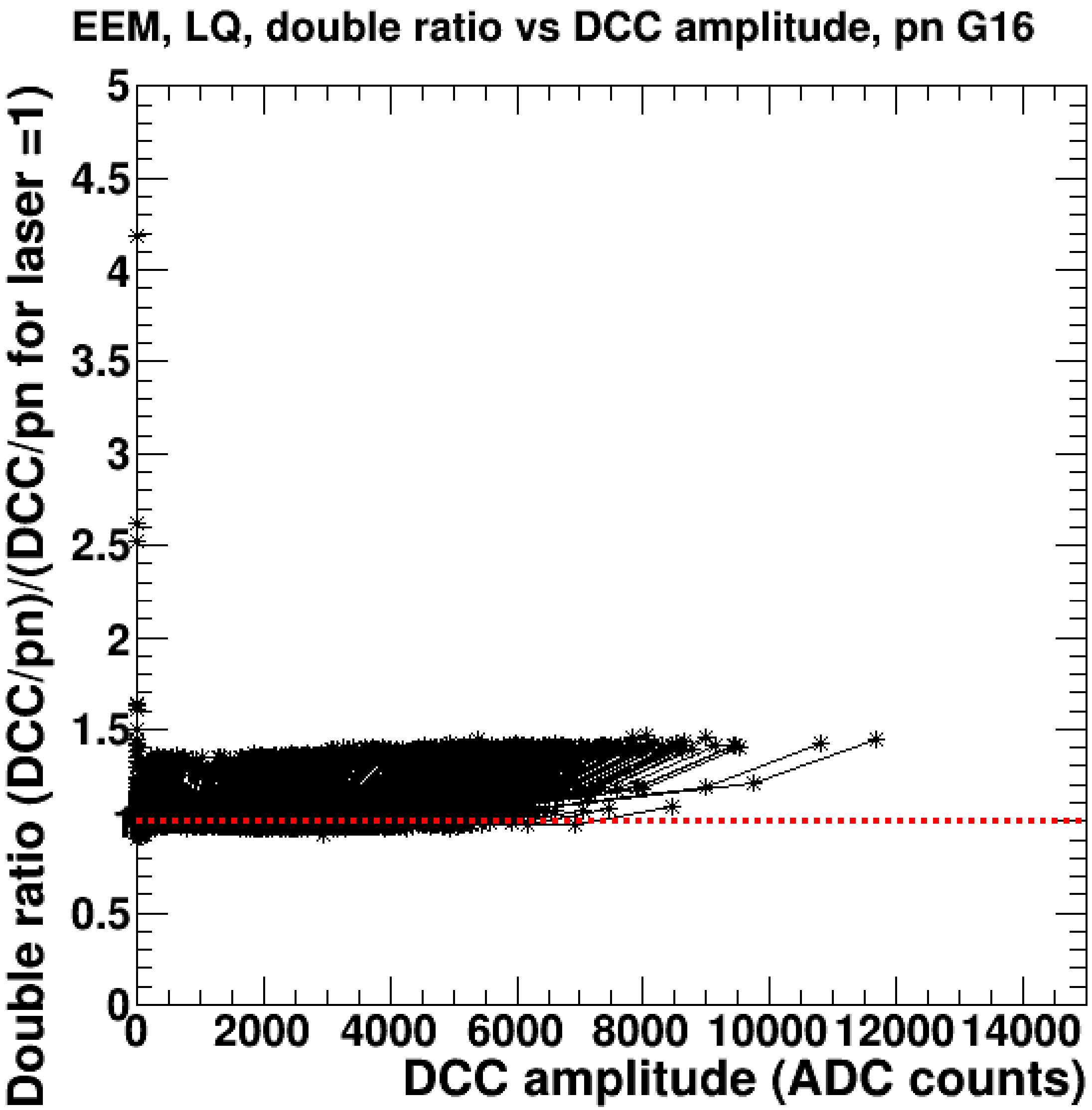
doublenorm[0] > 1.2, x = 61.50, y = 49.50, ref1 = 0.02092, ampscan[0] = 0.01443, doublenorm[0] = 1.45, amp = 1.60, pn = 76.51
doublenorm[0] > 1.2, x = 63.50, y = 48.50, ref1 = 0.01684, ampscan[0] = 0.00667, doublenorm[0] = 2.52, amp = 1.29, pn = 76.54

Transition from 3.8 T to 0.0 T, end of 2018

Laser runs at 3.8 T, Mon 3.12.2018,	DQM data
327604	OK
327587	OK

Laser runs at 0.0 T, Wed 5.12.2018,	DQM data
327693	Anomalous, low signals
327714	OK

Moral of the story – it is good that more than one run was taken for these reference data.


EEM, LQ, double ratio vs DCC amplitude, pn G16
Double ratio (DCC/pn)/(DCC/pn for laser =1)
DCC amplitude (ADC counts)
0
0.5
1.5
2
2.5
3
3.5
4
4.5
5
2000
4000
6000
8000
10000
12000
14000

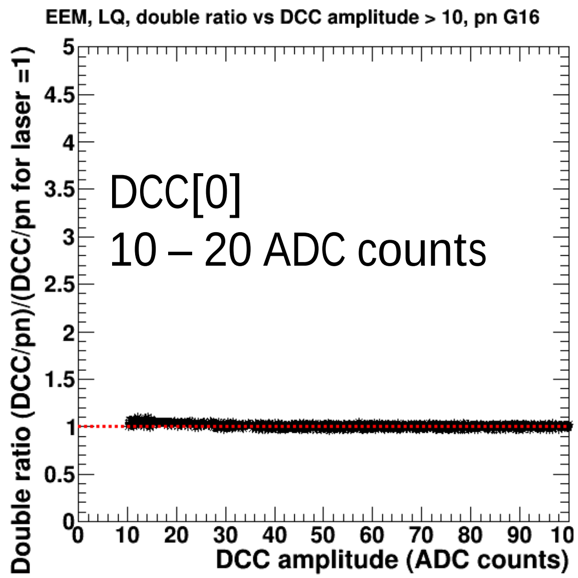
The double ratio, for DCC amplitudes up to 100 ADC counts, to focus on low end

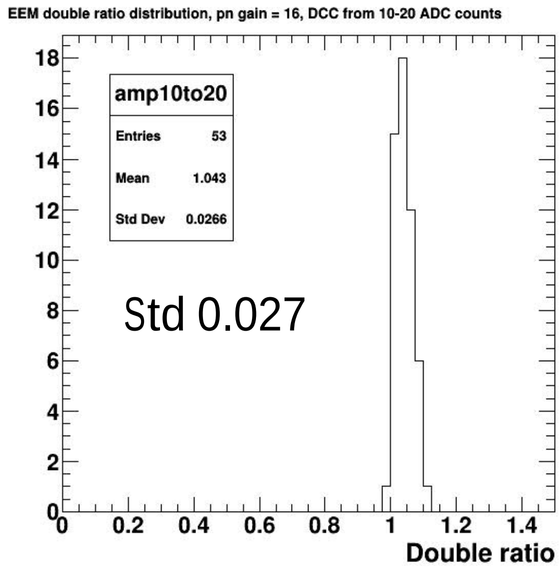
Top plot, if DCC between 10 and 20 ADC counts, at the lowest laser power

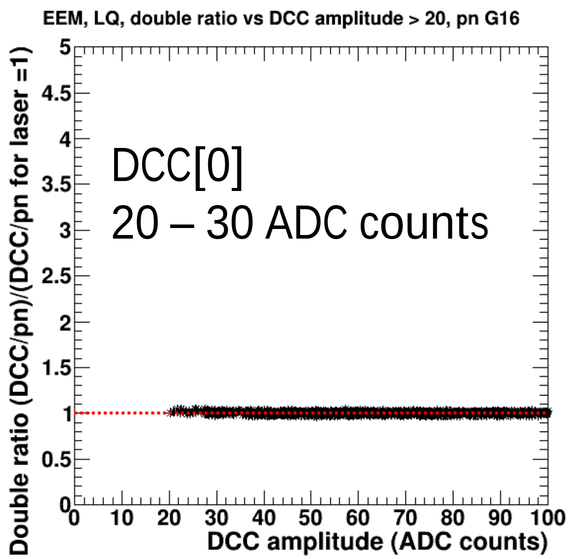
Bottom plot, if DCC between 20 and 30 ADC counts, at the lowest laser power

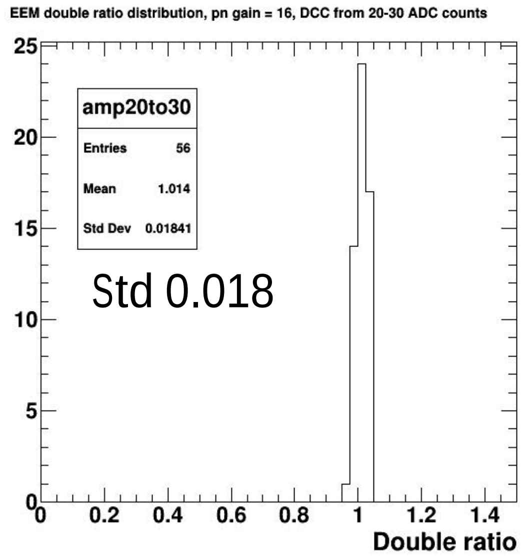
Double ratio is at ~unity at all amplitudes

Double ratio is narrower if all data are > 20 ADC counts.









Suggests target for minimum DCC amplitudes should be > 10-20 ADC counts

MiniDAQ laser data

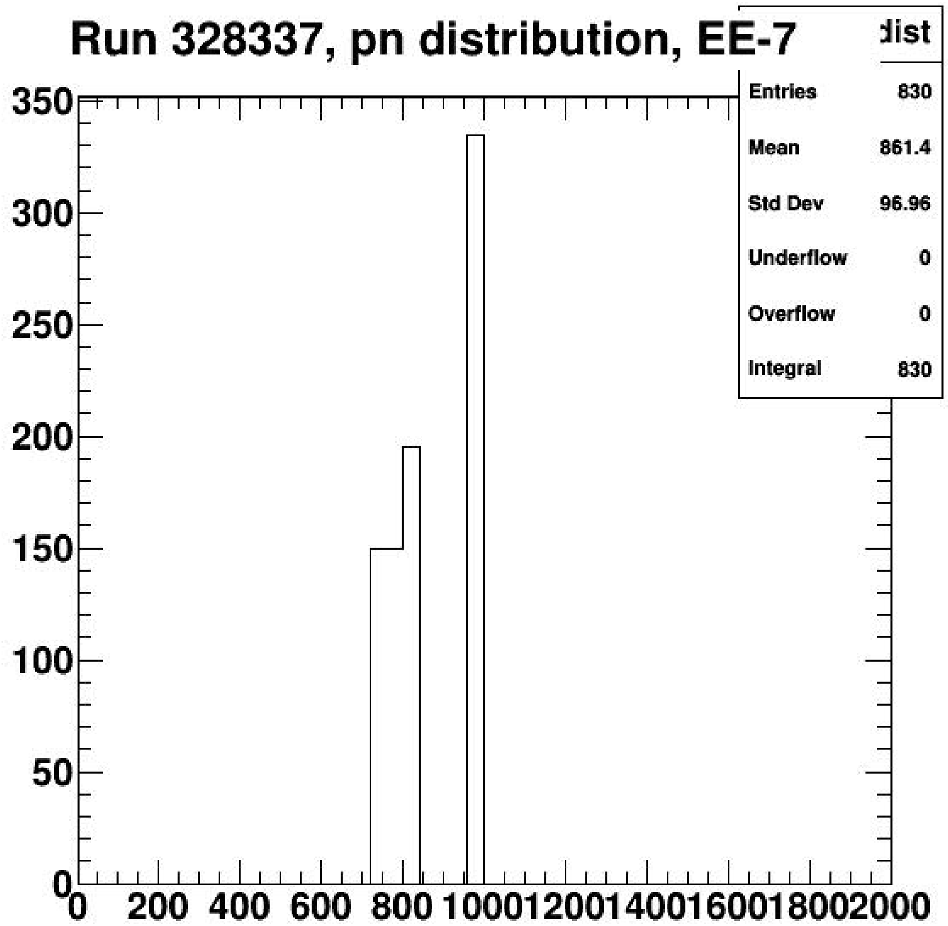
Individual channels:

- DCC amplitudes (ADC counts)
- DCC amplitudes/pn

⇒ Get individual pn values for each channel

Correctly see unique single pn value across each diffusing sphere region

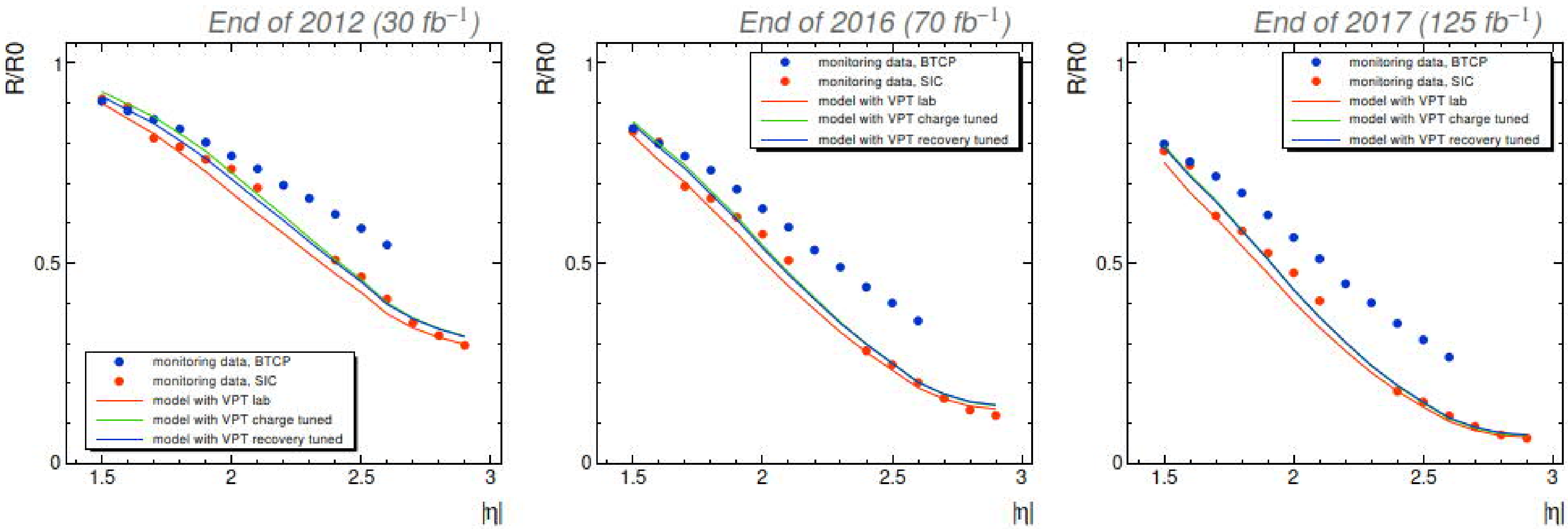
A useful cross check that the data are well behaved



Blue Laser for SIC and BTCP in EE

Comparison of monitoring data and model predictions in the middle of the LHC fill after several months of stable running.

Model describes evolution of SIC crystals well.



The original solid state laser in CR-2012/230, but never purchased

Pulse energy ~1.15 mJ at a pump current of 65 amps (110 mW at 100 Hz)

Similar to the in situ lasers, but needed higher operating currents

CMS CR -2012/230

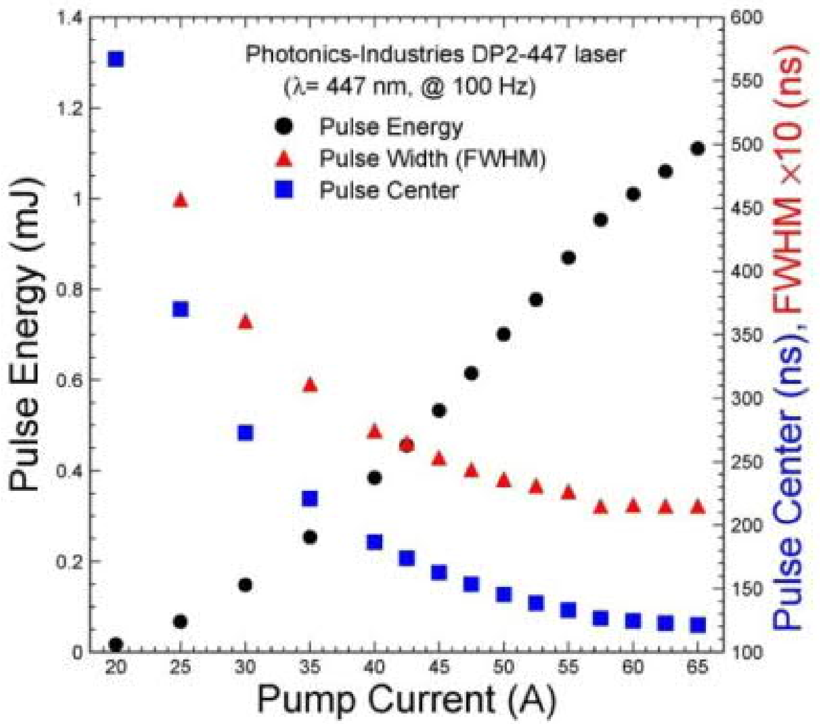


Figure 7. Pulse energy, width and center timing are shown as a function of the diode pump current.

The existing solid state lasers

Output power 100 – 110 mW at 100 Hz

= 1 mJ per pulse