Monitoring of the beam properties

A. Deur
Jefferson Lab

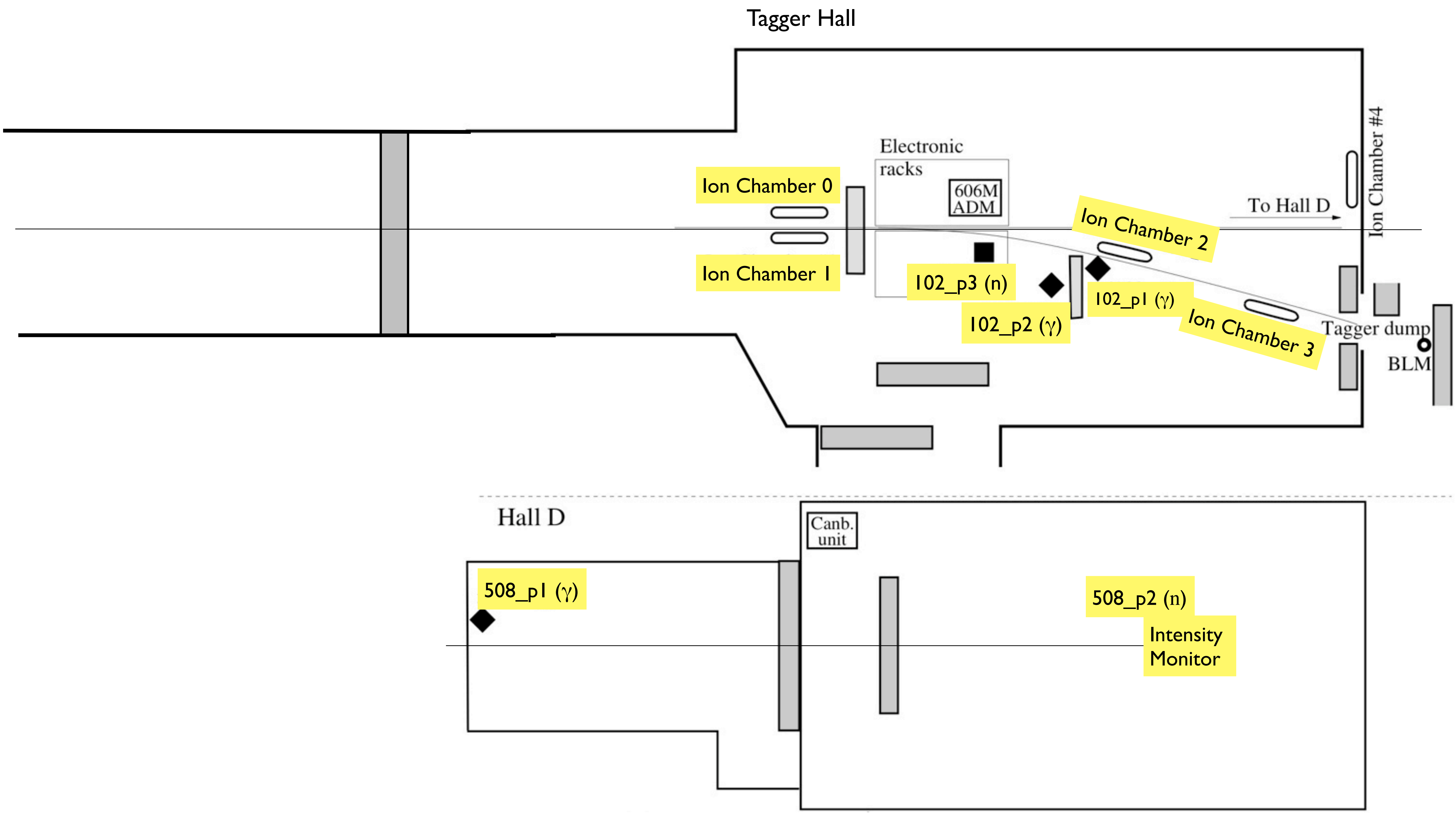
Summary of studies I did online.

⇒Analyses are incomplete.

⇒Hodgepodge of topics.

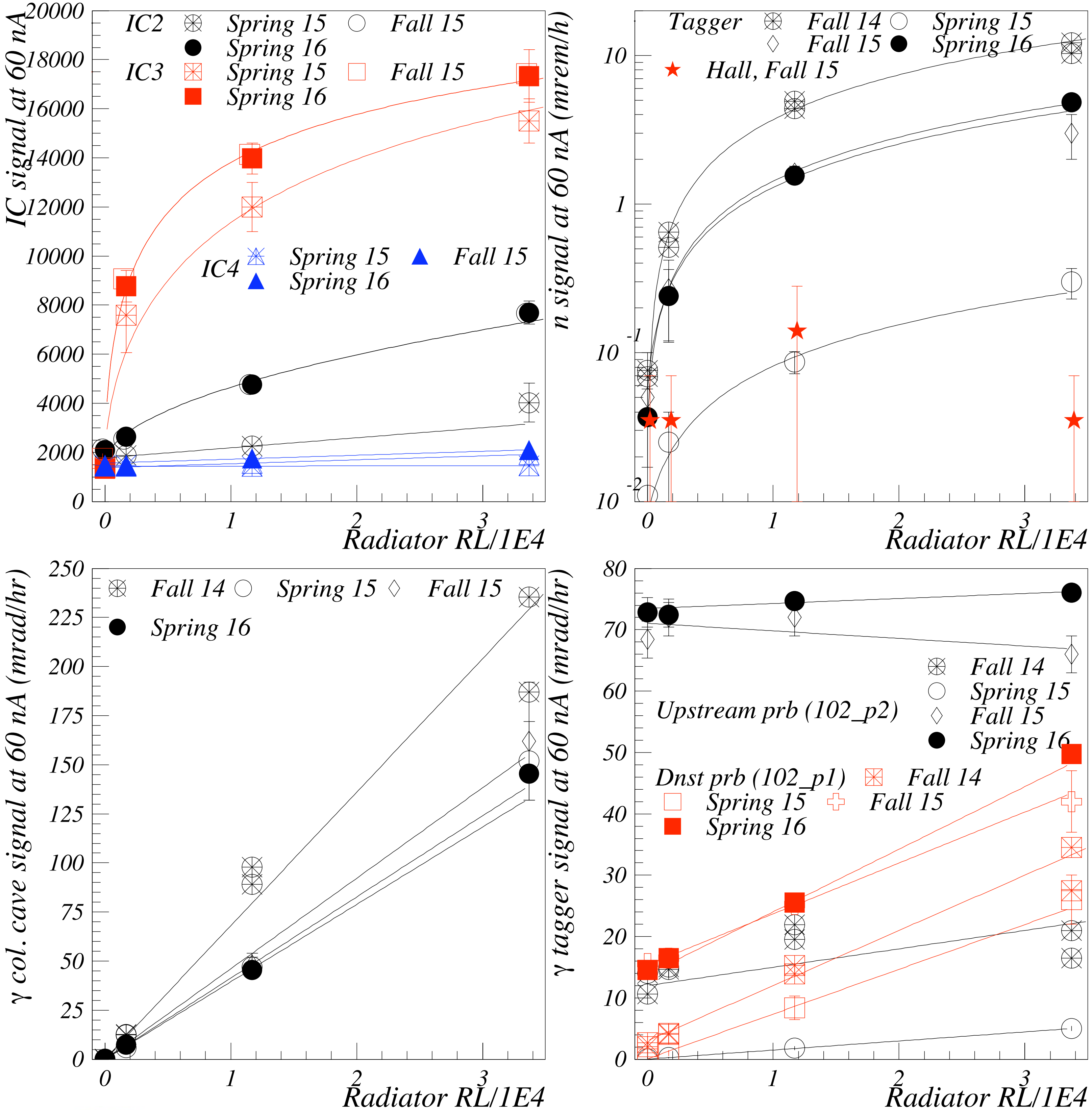
- Radiation monitoring
- Electron beam energy stability
- Photon beam transmission
- Diamond thicknesses
- Electron beam current monitoring

Radiation monitoring



Comparing Fall14 (10.1 GeV) Spring15 (5.5 GeV) and Fall15/Spring16 (12 GeV)

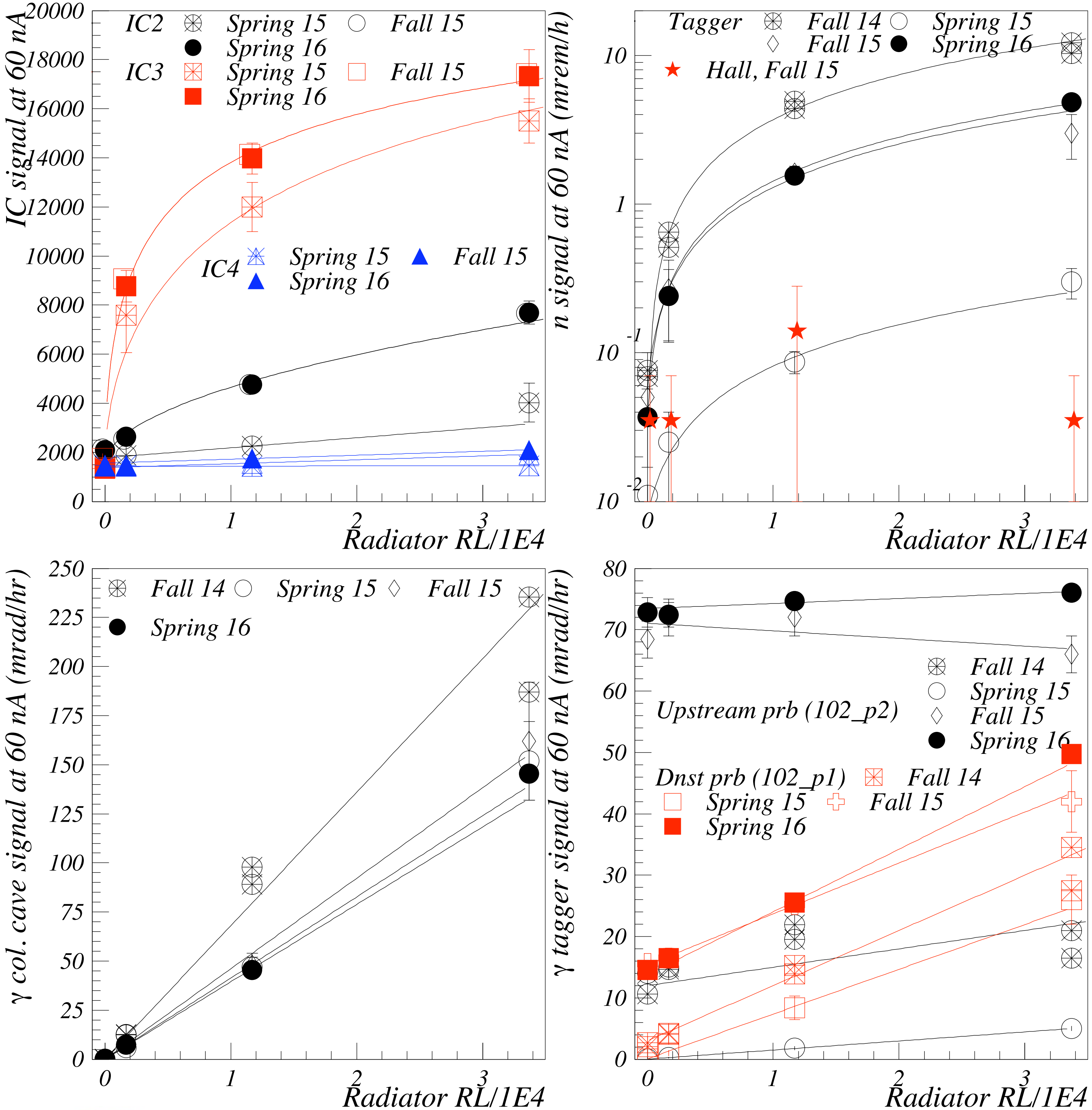
Rad. monitor dependences with radiator thickness



Spring 16 data: Mid Feb. 2016

Comparing Fall14 (10.1 GeV) Spring15 (5.5 GeV) and Fall15/Spring16 (12 GeV)

Rad. monitor dependences with radiator thickness



- (approx. values for Fall14. no error estimate)
- Similar levels in Fall15 and Spring 16. Worst than Spring 15.
- See expected linear dependence with RL for γ and n probes in tagger/collimator cave.
- See expected log dependence for ICs. Rates now high enough for IC2 to show log dep.
- Spring15: IC0, IC1, IC4 insensitive to RL or beam current (unless the beam is not well tuned). Fall15: IC4 sensitive to both.
- Fall14, Fall15, Spring16: 102_P2 very large and independent of RL. Beam hit tagger entrance? Compatible with low energy electrons background sometimes seen in hodoscope. (Spring15 RL-dependence fixed by adding tagger shielding)

Comparing before and after beam tune improvement during Spring 16 run

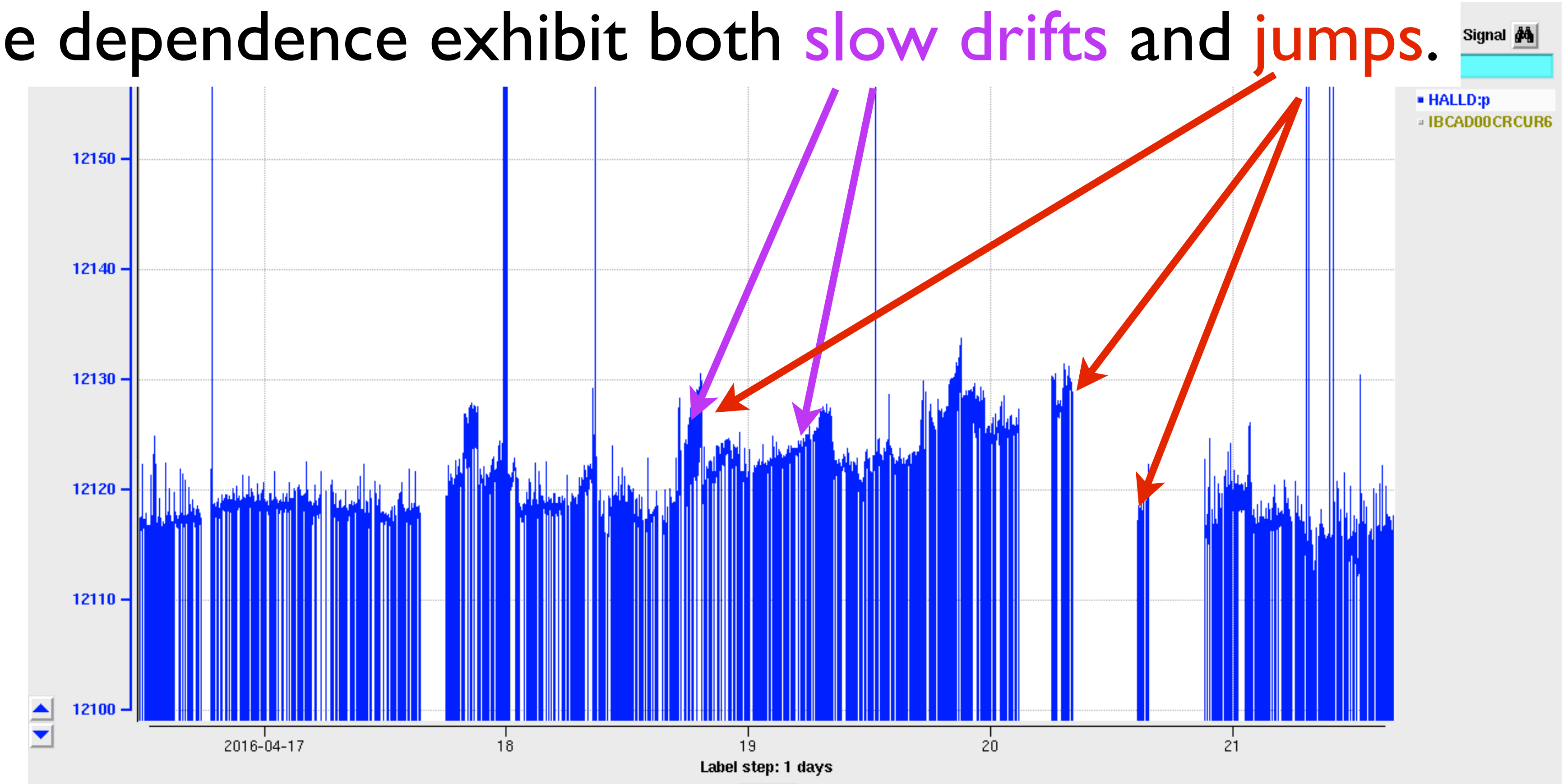
	March 8th	April 7th
Beam current	175 (210) nA	210 nA
photon probe, collim. cave	280 (336) mRem/h	294 mRem/h
neutron probe, Hall	0.26 (0.31) mR/h	0.27 mR/h
Up photon probe, tag. vault	175 (210) mRem/h	200 mRem/h
dwn photon probe, tag. vault	90 (108) mRem/h	110 mRem/h
neutron probe, tag. vault	8.5 (10.2) mR/h	10 mR/h

No significant changes seen on radiation monitors. However, new tune decreased background seen by FDC (allowed to run at higher current with less trips).

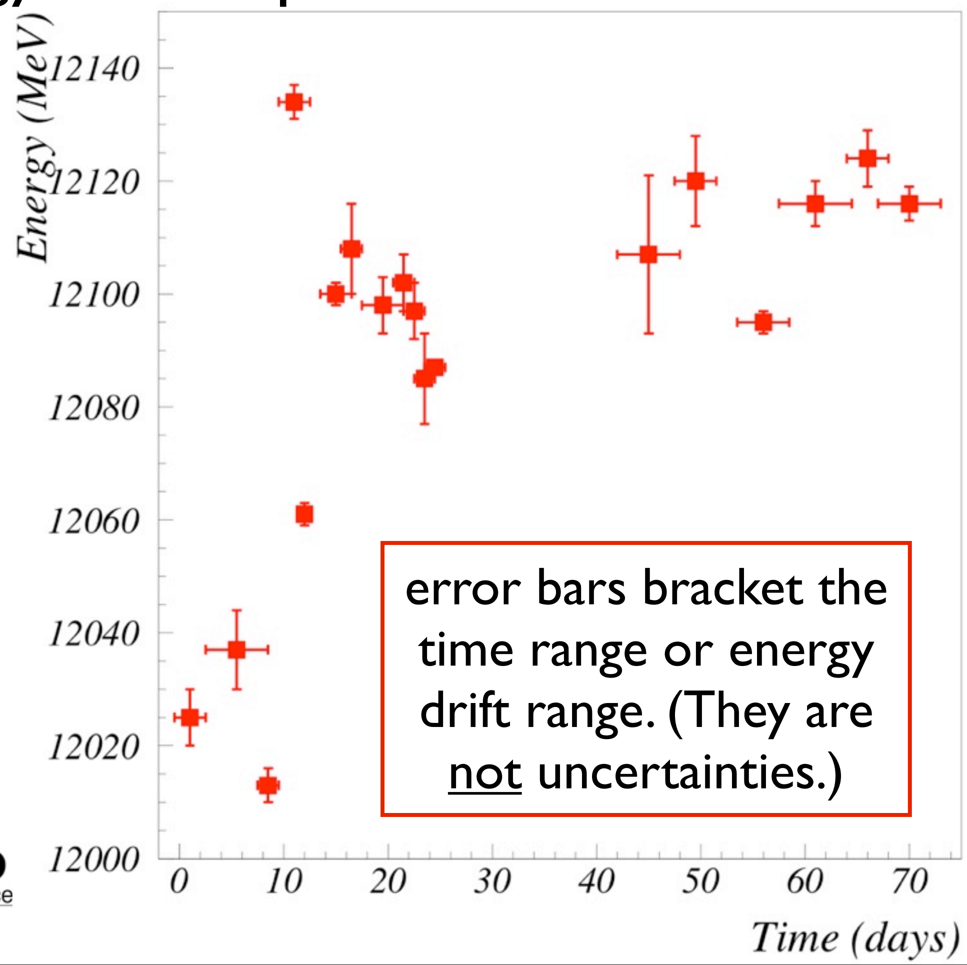
⇒Radiation monitors are useful only for assessing whether initial beam tune is acceptable.

Beam energy stability

Energy time dependence exhibit both slow drifts and jumps.



Rough energy time-dependence for the full run, binned in period of approximate stability:



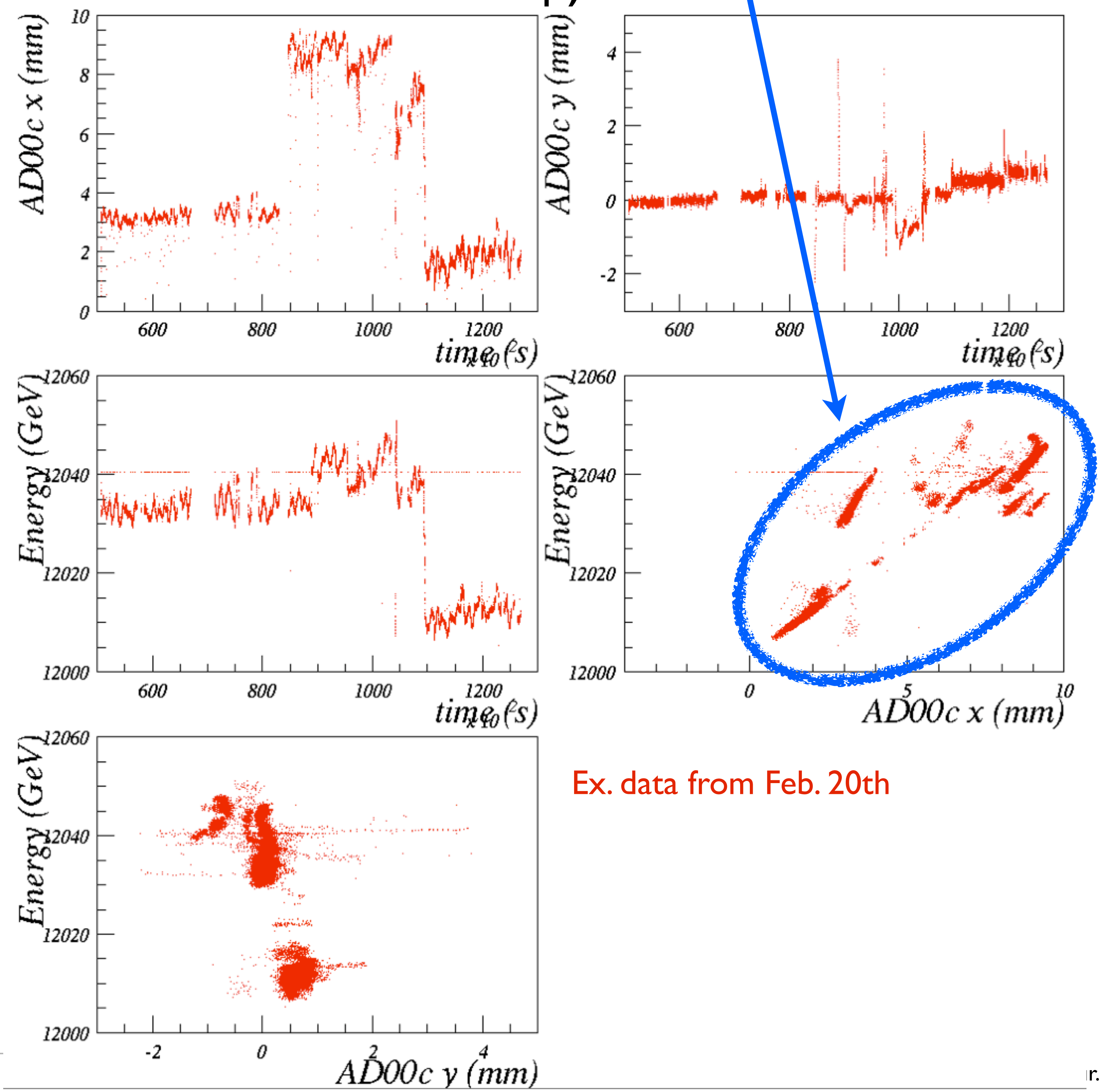
Time	energy (HALLD:p) (MeV)	Note
02/13-02/15	12025±5	
02/16-02/21	12037±7	02/16: 0:00 to 8:30am: Steady 13MeV up drift
02/21-02/22	12013±3	jump from 12037 to 12013 MeV around midnight.
02/23-02/25	12134±3	Beam down for 16h. Came back at 12133 MeV
02/25-02/25	12061±2	jump down on 02/25 at 10am.
02/27-02/29	12100±2	
02/29-03/01	12108±8	noticeable systematic drifts
03/02-03/05	12098±5	
03/05-03/06	12102±5	
03/06-03/07	12097±5	
03/07-03/08	12085±8	
03/08-03/09	12087±1	
03/27-04/01	12107±14	slow systematic drift from 12093 MeV (03/27) to 12120 MeV (04/01)
04/01-04/04	12120±8	
04/07-04/11	12095±2	Beam down for 3days. Came back at 12095 MeV. Short times at 12101 MeV
04/11-04/17	12116±4	Beam down for 6h. Came back at 12115 MeV.
04/17-04/20	12124±5	Beam went down on 04/17 15:23. Came back at 12121 MeV, less stable, with overall systematic up drift.
04/20-04/25	12116±3	Short times at 12111 MeV

Beam energy stability

Energy is measured from the beam position in the Hall D ramp.

Drifts (typically a few MeV, at worst 10 MeV):

Seem to be real: They correlate with x-position (and not y) of the beam after tagger magnet (AD00c BPM in the beam dump).



Ex. data from Feb. 20th

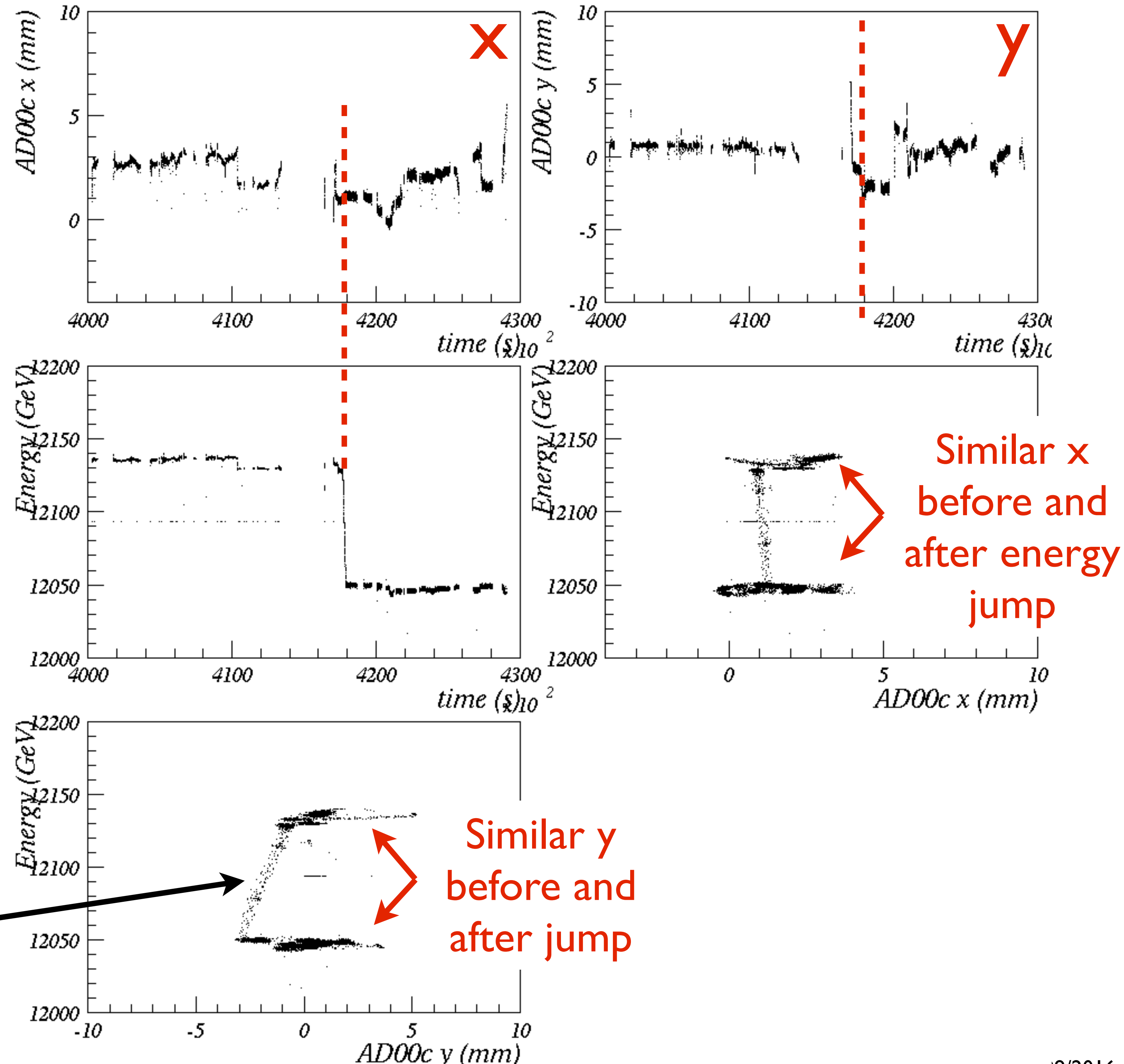
Beam energy stability

Energy is measured from the beam position in the Hall D ramp.

The largest jumps (30 to 100 MeV) are believed to be artifacts:

- The beam pipe size cannot accommodate the change in orbits that would follow such jumps

- No x or y correlations with energy.

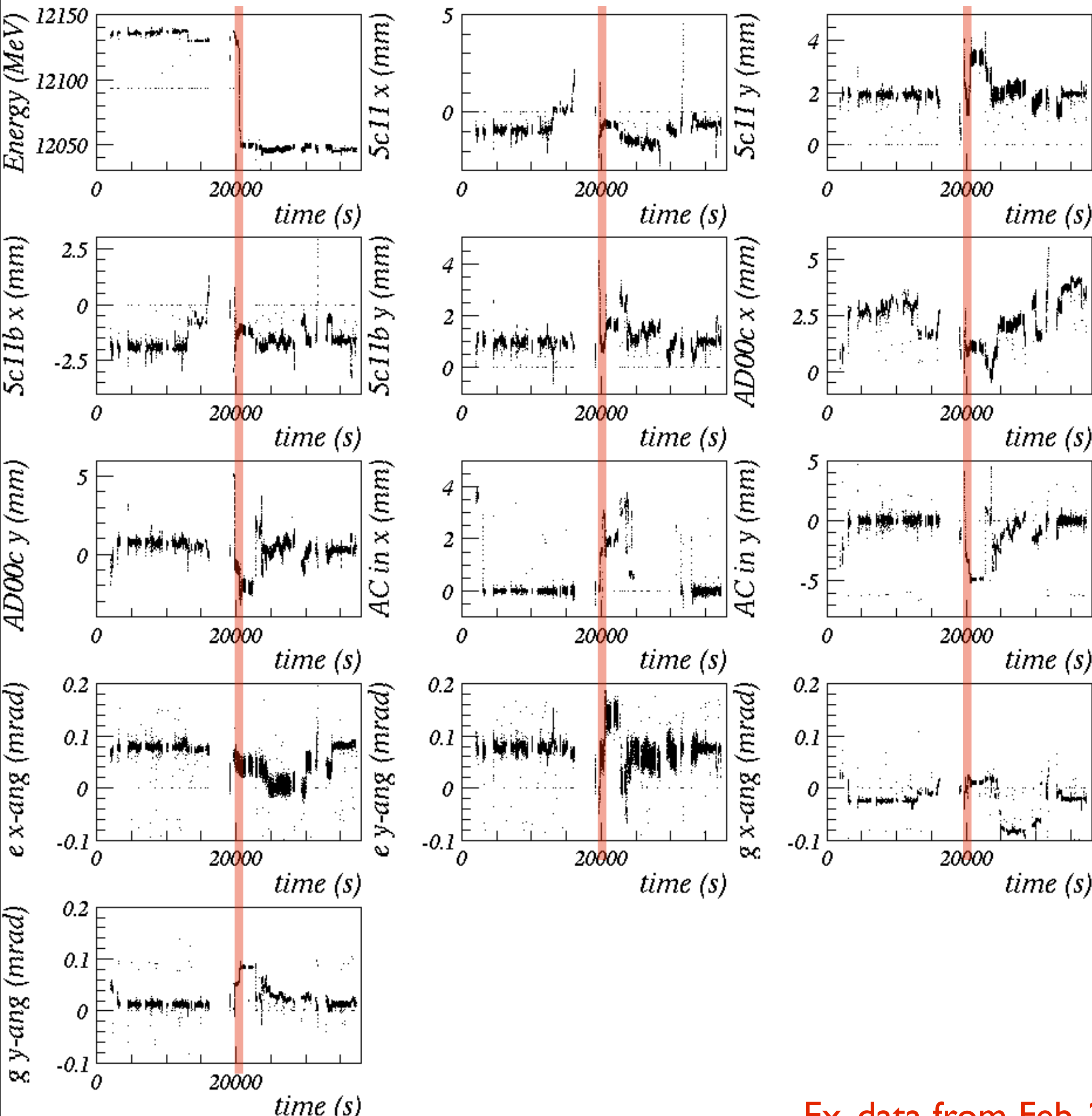


Change in y at the time of the jump. Then back to usual position. PID slow locks were implemented at that time.

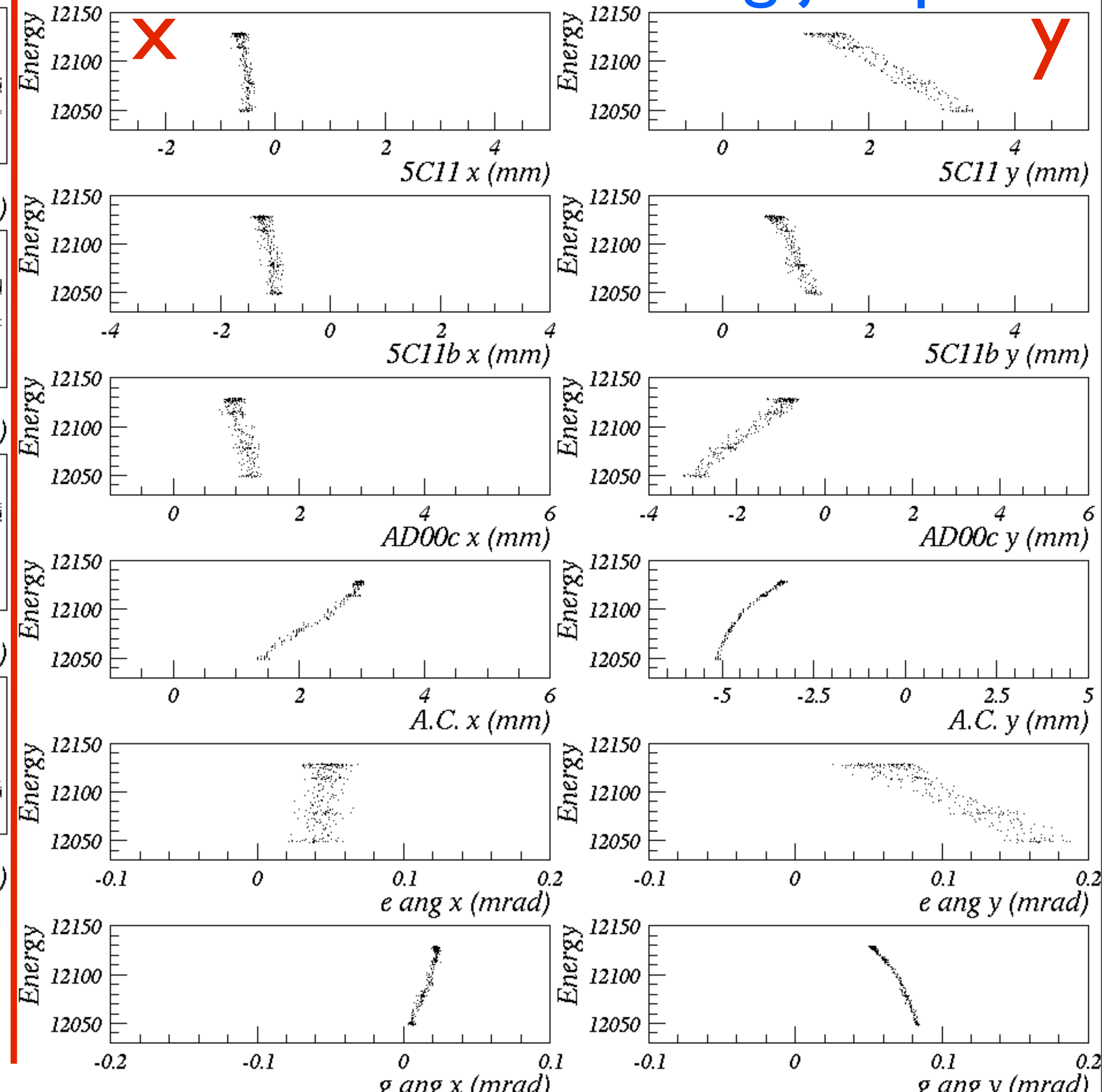
Beam energy stability

Also looked if the energy jumps are correlated with electron beam positions and angles before tagger magnet. Change in y position in angle at the time of the jump (source of the jump?).

Time evolutions



Correlations during jump



Ex. data from Feb. 25th.
PID slow locks were implemented on Feb. 19th

Photon beam transmission

•Photon transmission optimized by x & y Act. Col. scans. (First thing done when beam is establish/re-establish after significant down time or retune.)

•Is transmission better for different radiators? ("50 μm" diamond vs "20 μm" diamond vs AL. radiator)

•Ongoing mystery during Spring run: RL-normalized event rates different for para and perp diamond orientation: up to 50% difference. (log entries: 3386252, 3389907). True for both "50 μm" diamond (e.g. Feb. 20th 10am) and "20 μm" diamond (e.g. Feb. 29th 3am), although the effect is smaller for the "20 μm" diamond.

- •Could electron beam hit different part of the diamonds? But "50 μm" diamond has no thicker frame.
- •Could beam profile be different for para and perp, and Act. Col. feedback imposes different electron beam positions? Flux change correlated with corrector magnet setting (log entry 3389907).

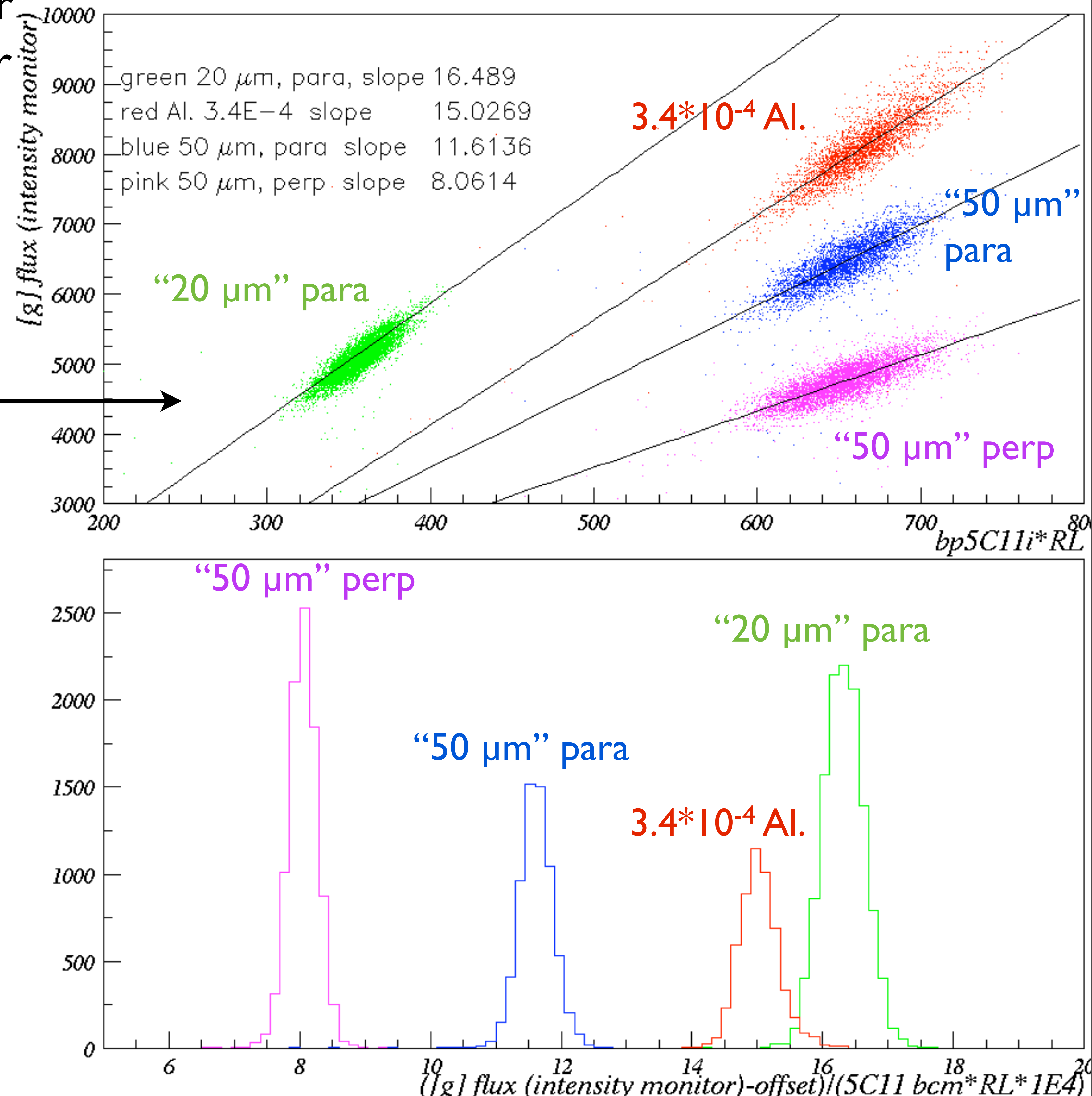
After talk addendum: The above hypothesis is ruled out by a position study from Hovanes and Mark Dalton. Also, Havanes showed that the discrepancy is also present when the feedback is off. The problem appears to comes from the fact that the position of the diamonds (wrongly) changes during rotation (see Tim W's talk). The beam centering on the diamond was verified only for the // case. Because of the displacement, the beam was on the edge of the diamond in the perp. case. This explains why the perp rate is smaller, why the effective RL in the perp case is smaller than in the para case (see next slides) and why the photon flux jitter is larger in the perp case and correlated with position jitter (See Hovanes talk)

- •Beam scrapping? (unlikely at the 30% level: incoherent background similar for para and perp)

Photon beam transmission

If transmission is the same for different radiators, and if their RL are known, then intensity monitor signal and RL*I_{beam} should have a unique correlation slope.

Not true: 4 different slopes.



Slope values:

Photon beam transmission

⇒ Transmissions for different radiators are different

or

the effective RL are different from thicknesses listed in from U.Con. diamonds Table

or

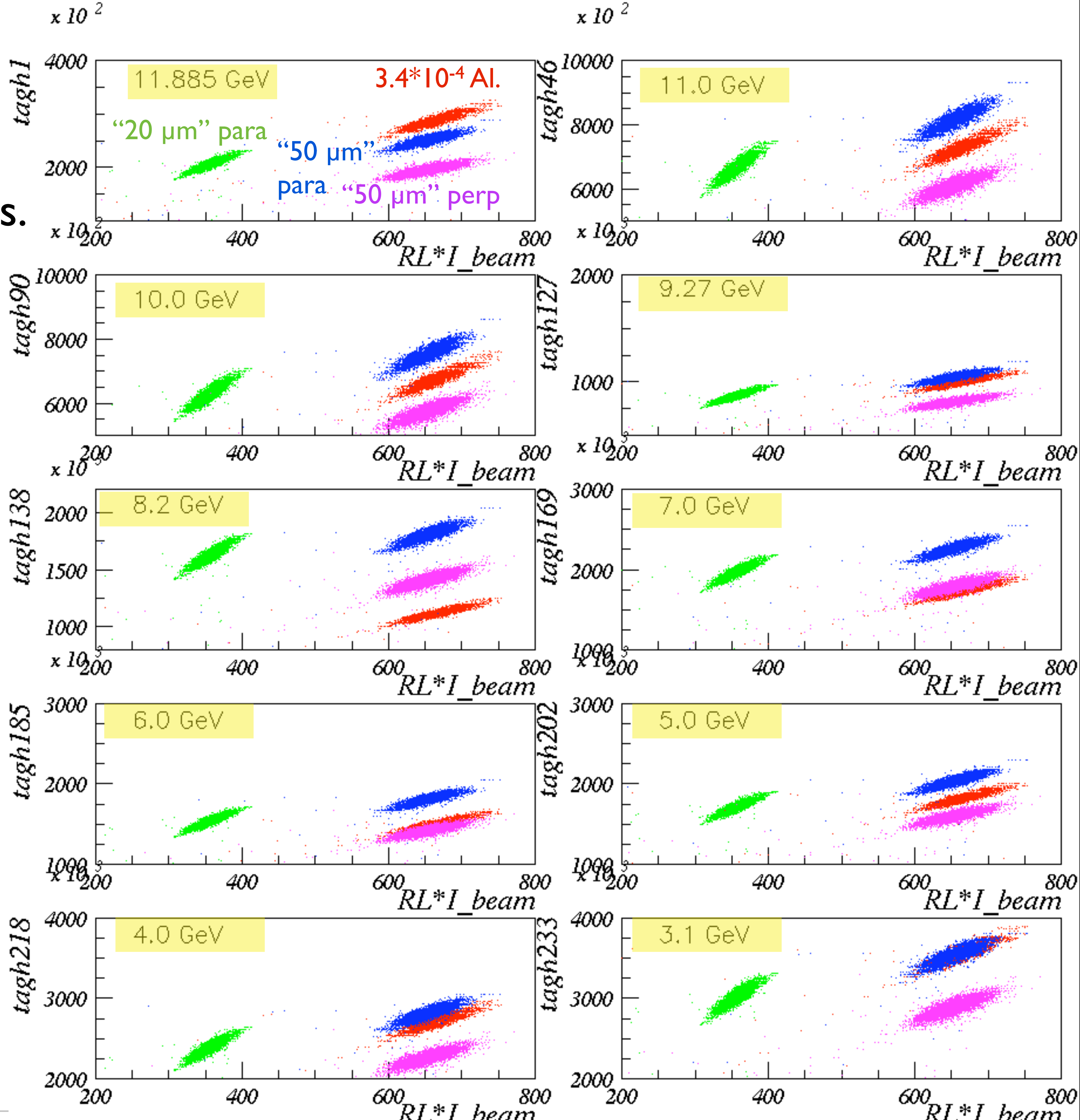
Scrapping occurs (ruled out by polarimetry analysis)

Photon beam transmission

Similar effect seen on TagH counters vs RL*I_{beam}:

⇒rules out different transmission hypothesis.

⇒Problem with RL values.

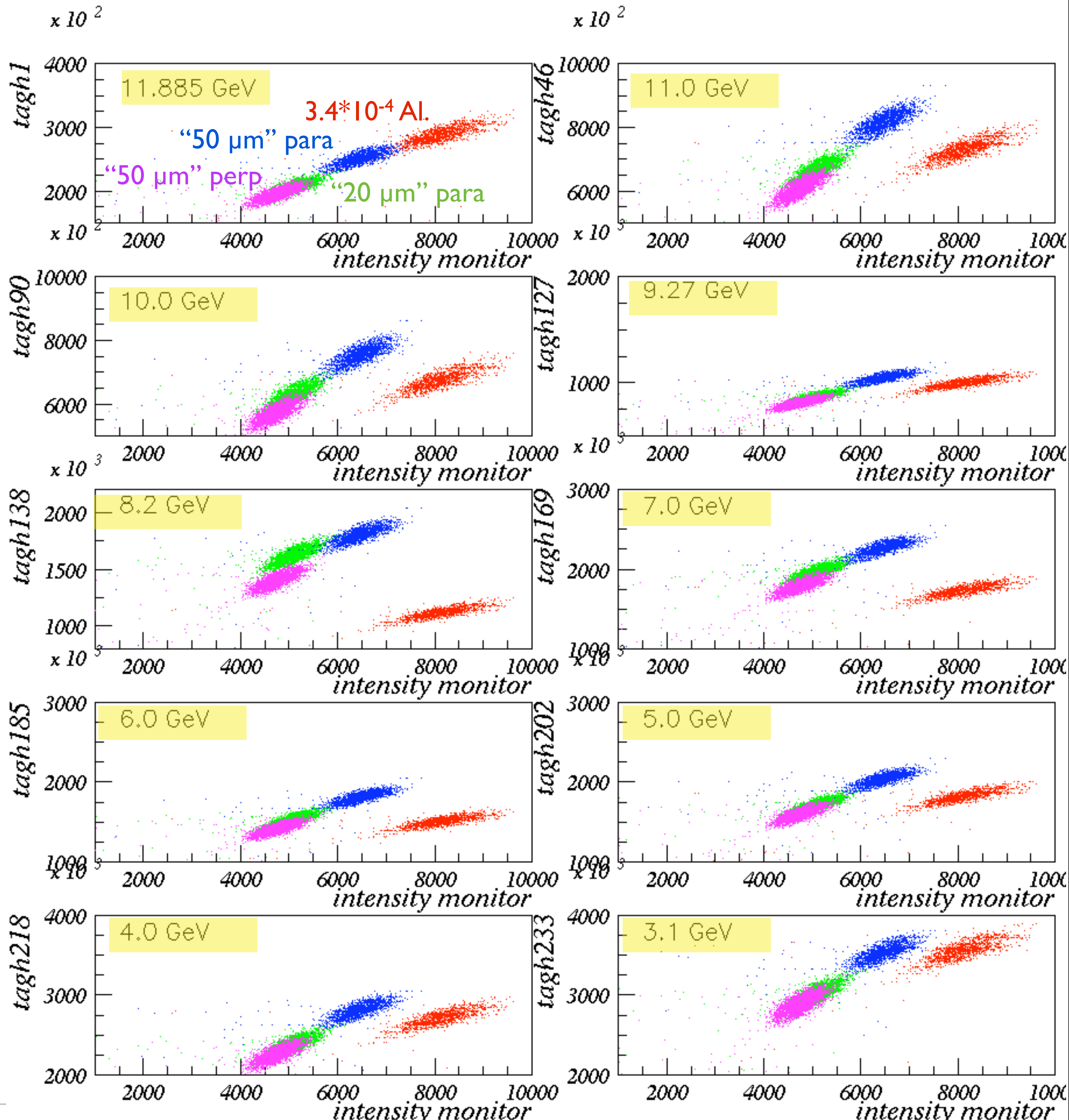


Photon beam transmission

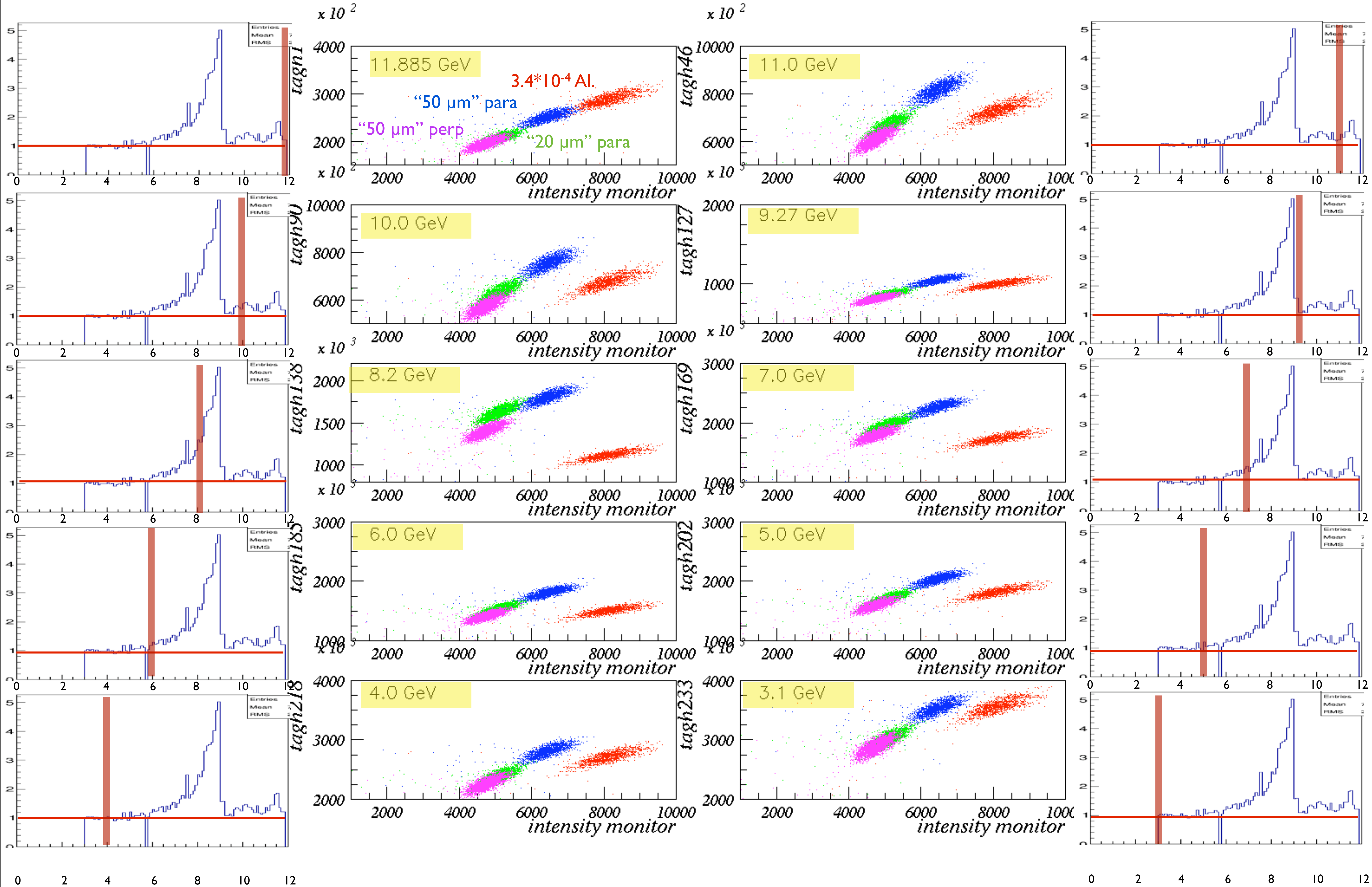
Effect not seen with TagH counters vs Int. Monit.:

Apparent wandering of the red spot:

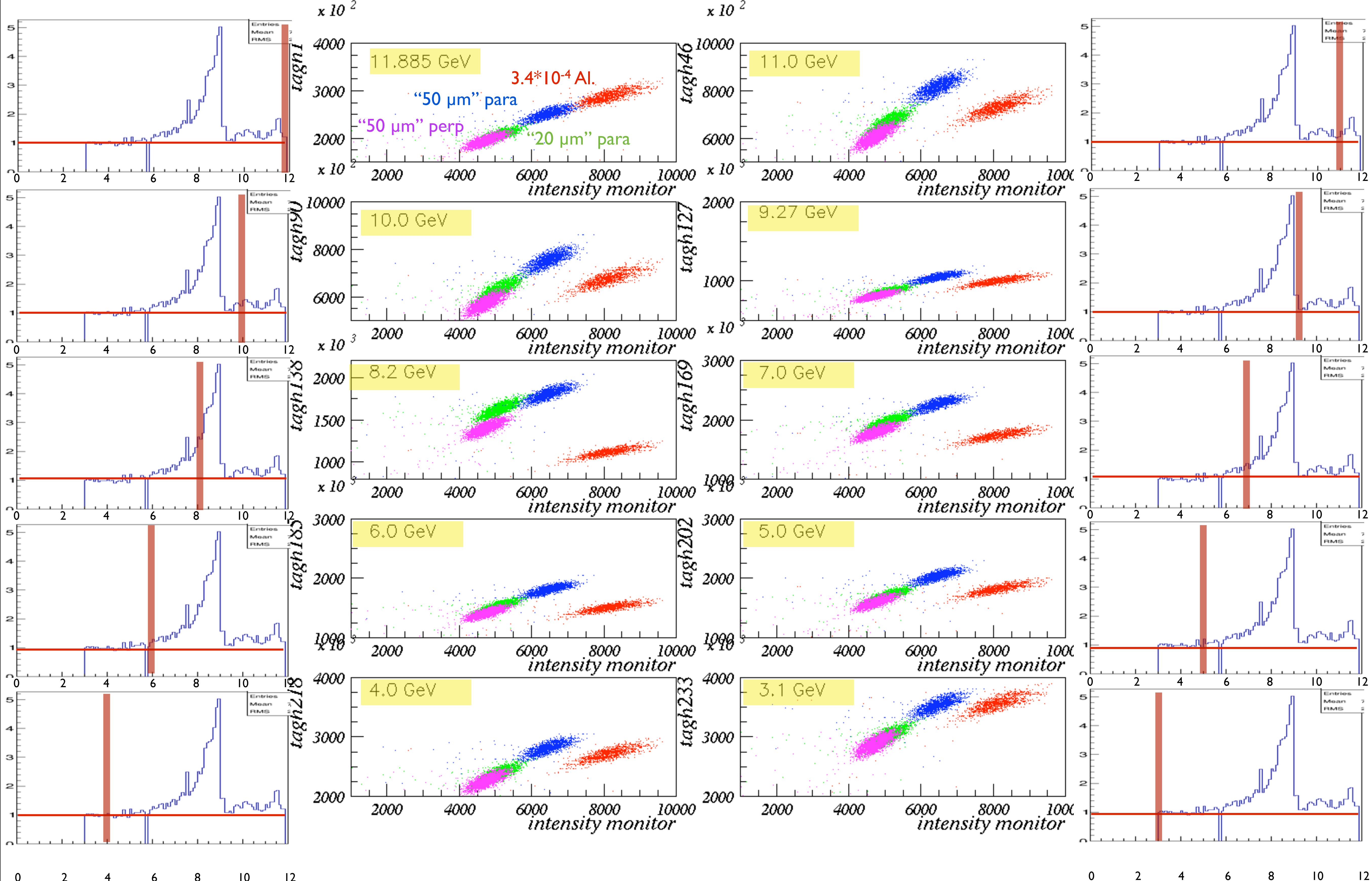
Red spot is stable (follow bremsstrahlung spectrum). Other spots get enhanced due to coherent peak.



Photon beam transmission



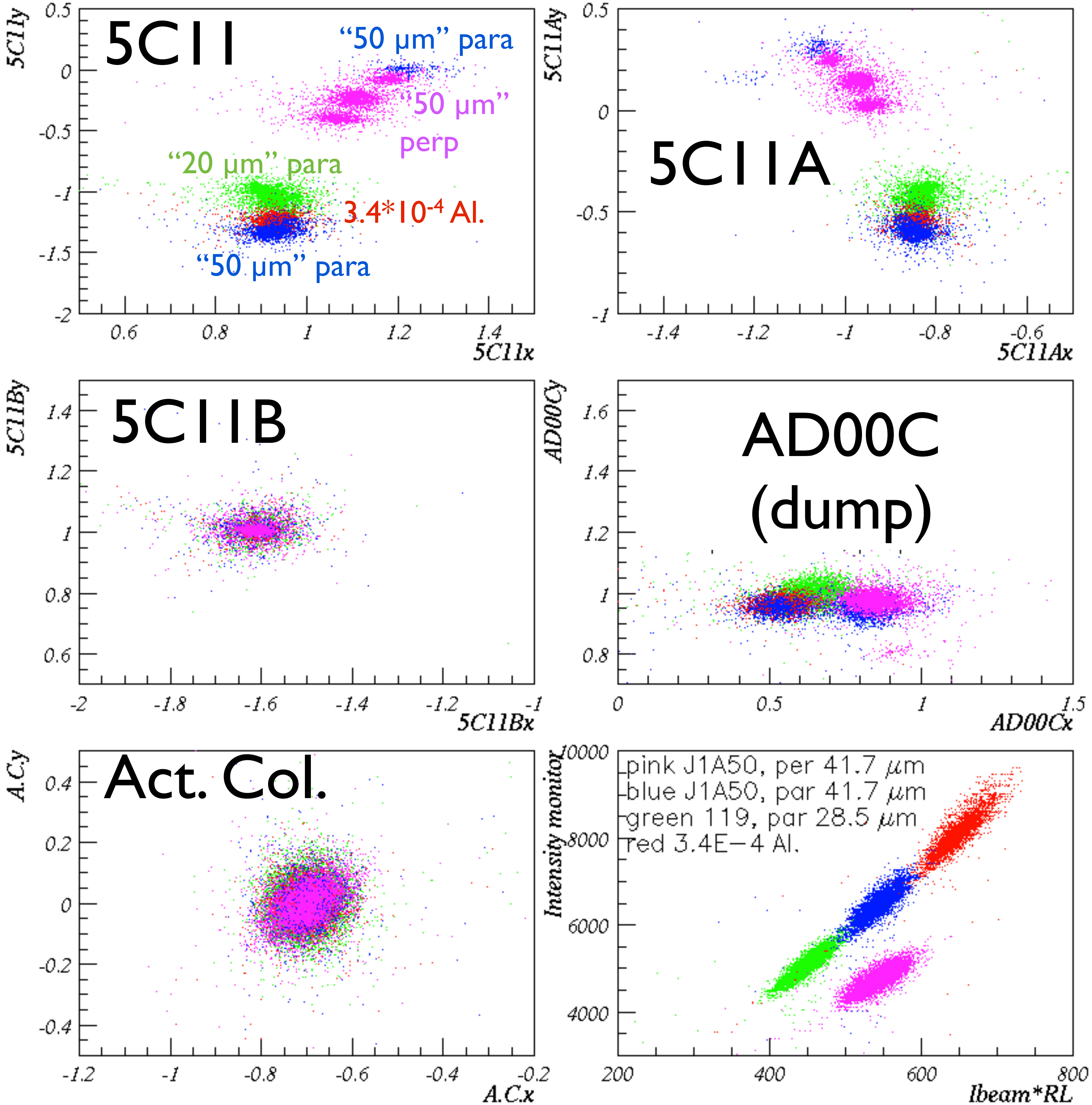
Photon beam transmission



Still see coherence at low energy (3.1 GeV)

Photon beam transmission

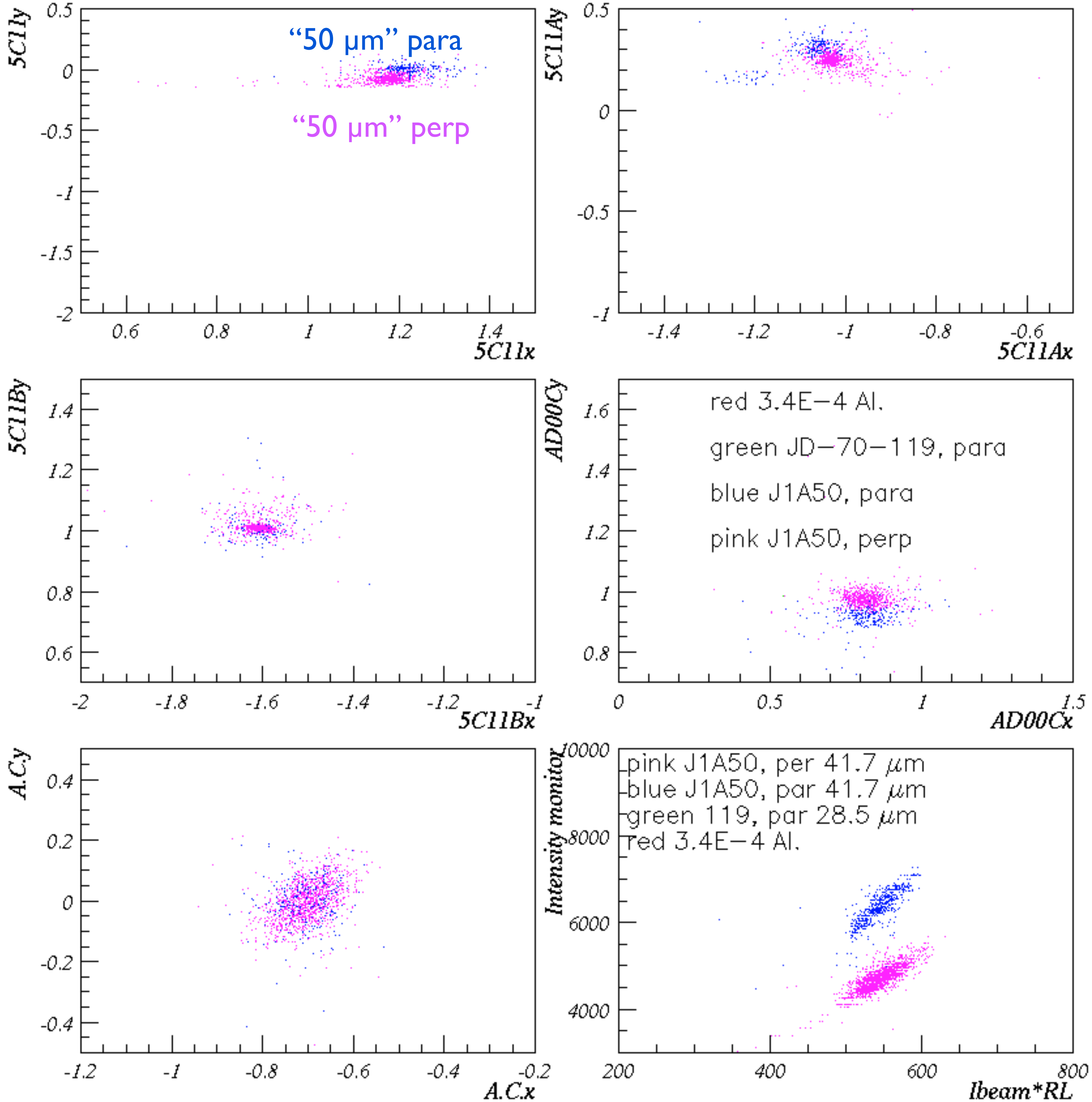
Influence of beam position and angle on photon flux



- Beam roughly on the same spot expect for "50 μm" perp and "50 μm" para for a short time.
- spots for 5C11B and A.C. are the same (consequence of slow feedback enabled).

Photon beam transmission

Beam position dependence with radiator type:



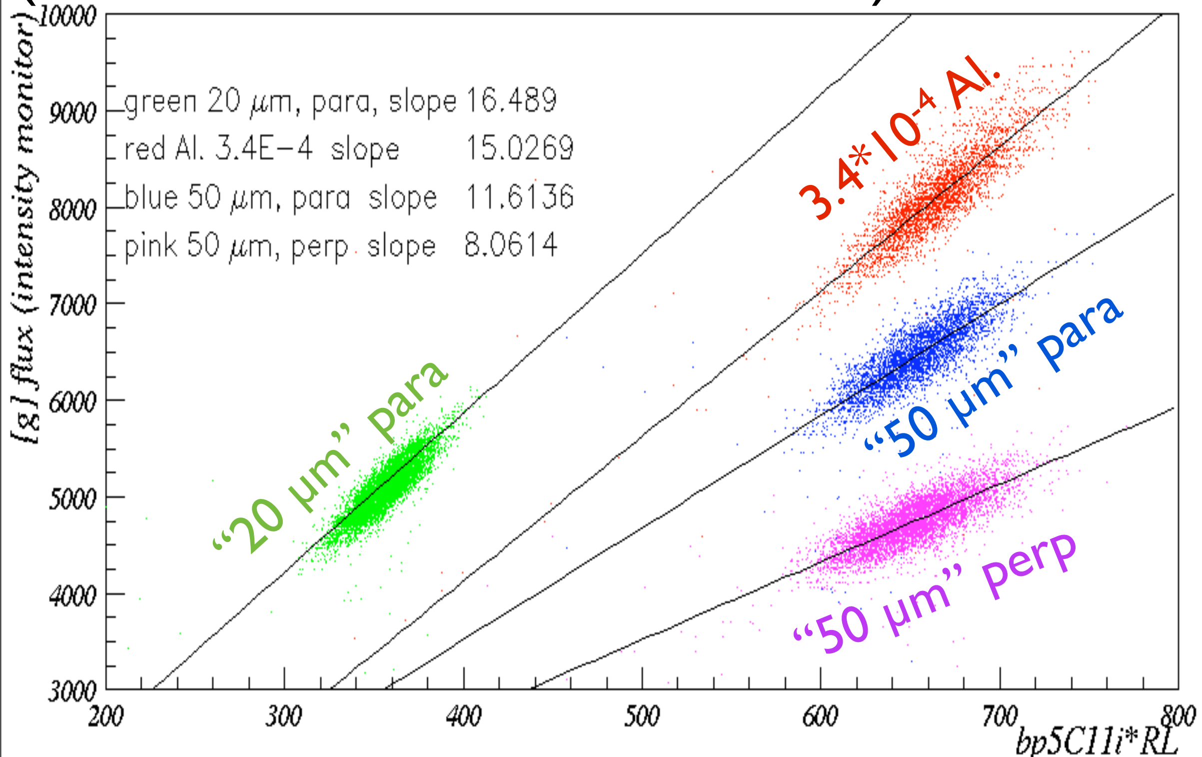
Same beam spot but different transmission.

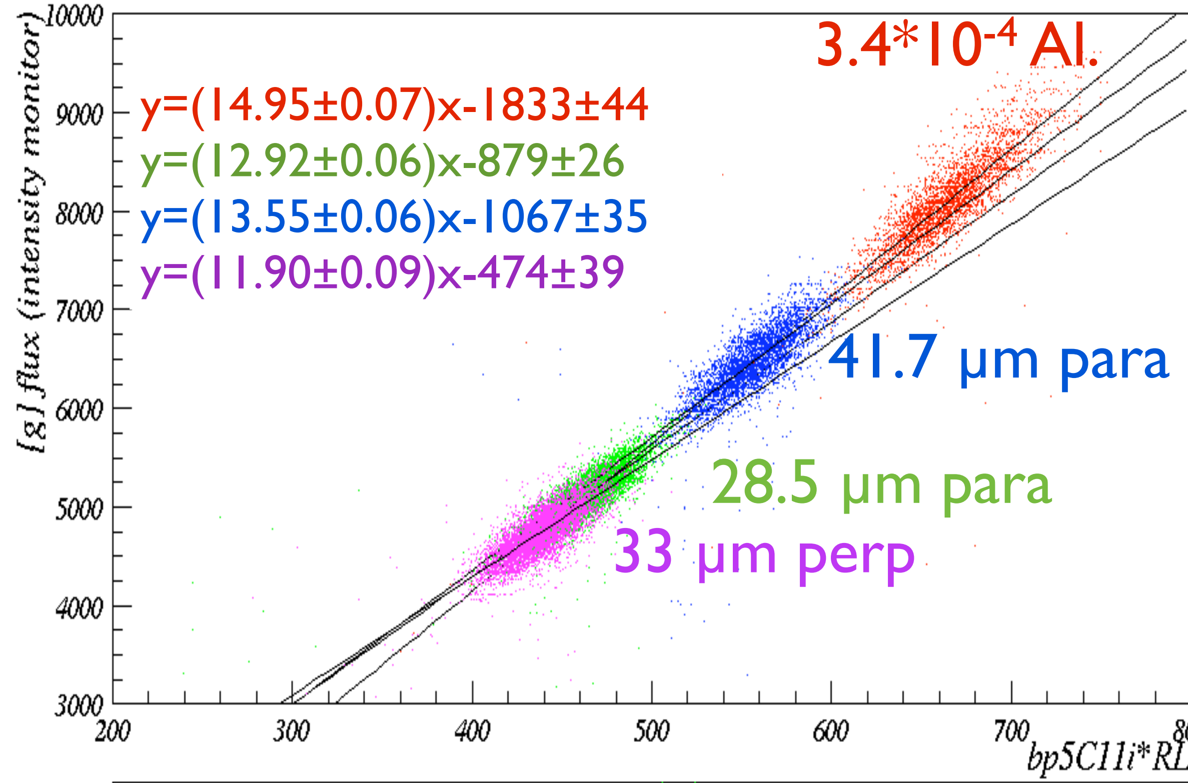
⇒ Discrepancy not due to beam position and angle

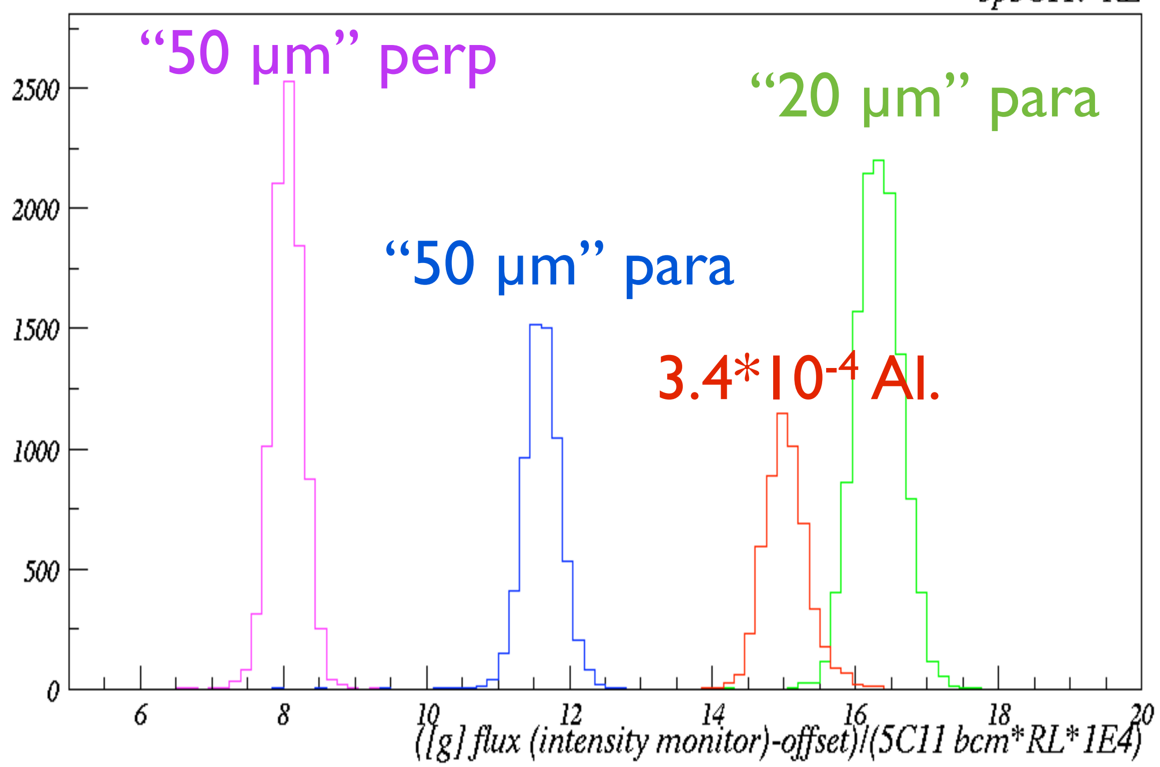
Photon beam transmission

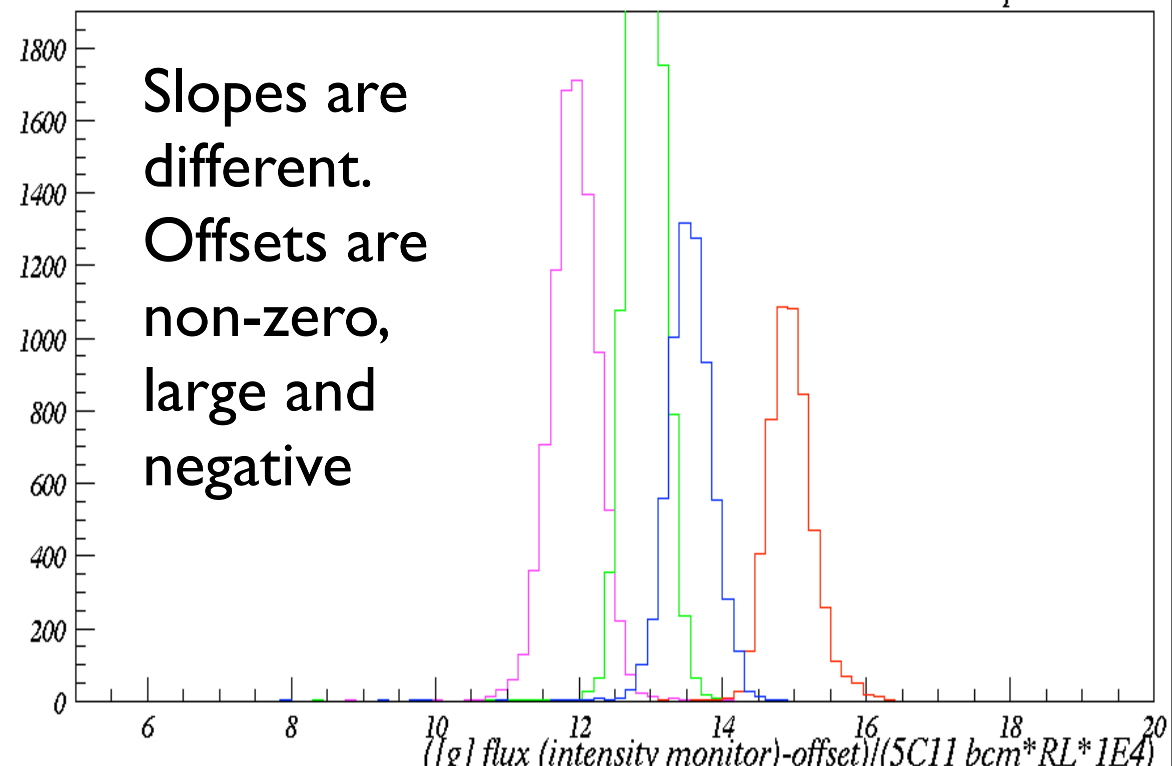
Once can estimate the effective diamond RL relative to Al. RL by aligning the spots.

(no coherence effect on BPM*RL).









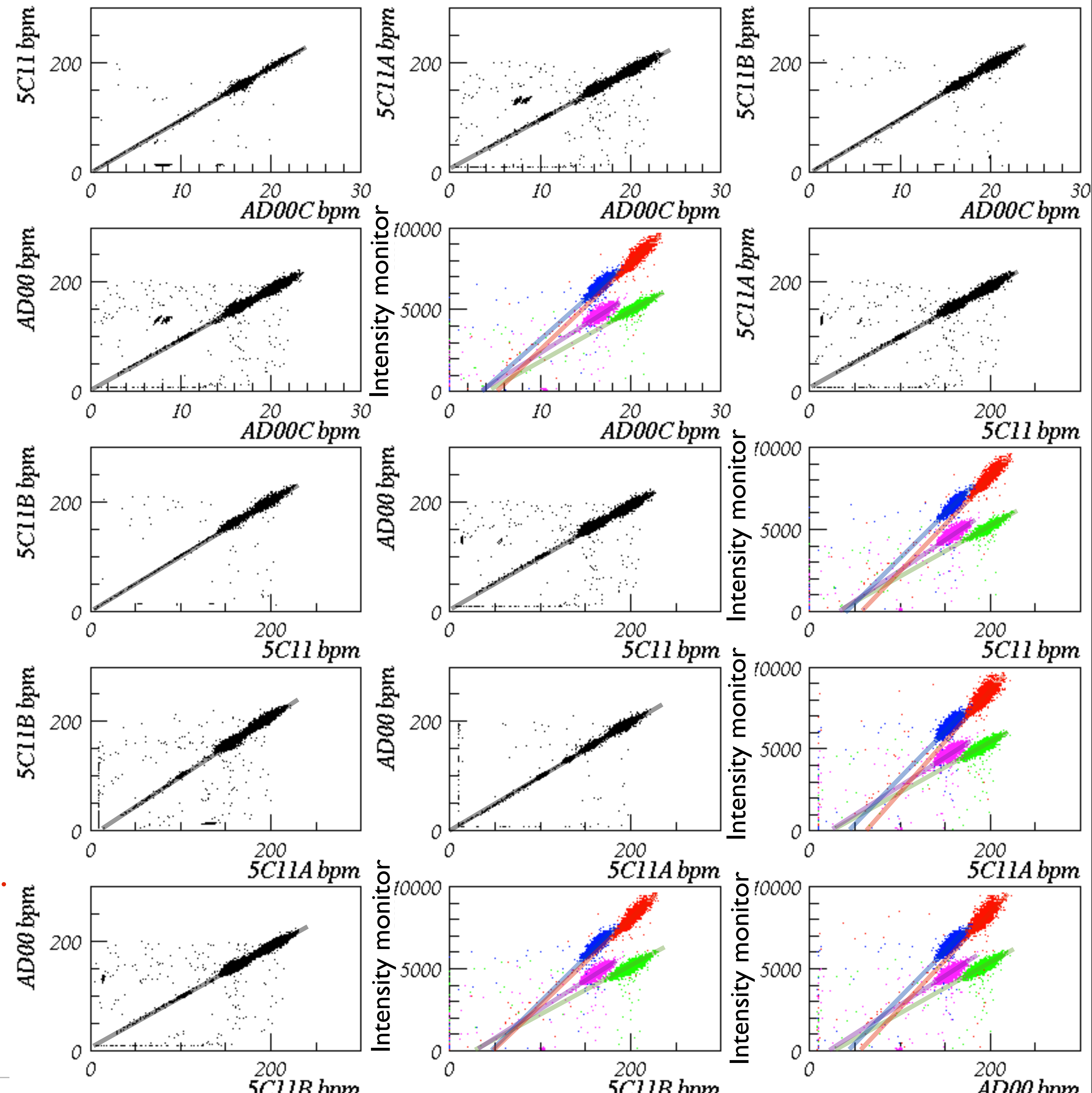
BPM or intensity monitor non-linearity? BPM offset?

different beam backgrounds/transmission?

Poor fits? (χ^2 between 1.5 and 2)

Photon beam transmission

Current monitors linearities:



BPM correlations show very small offsets (<5nA typically)

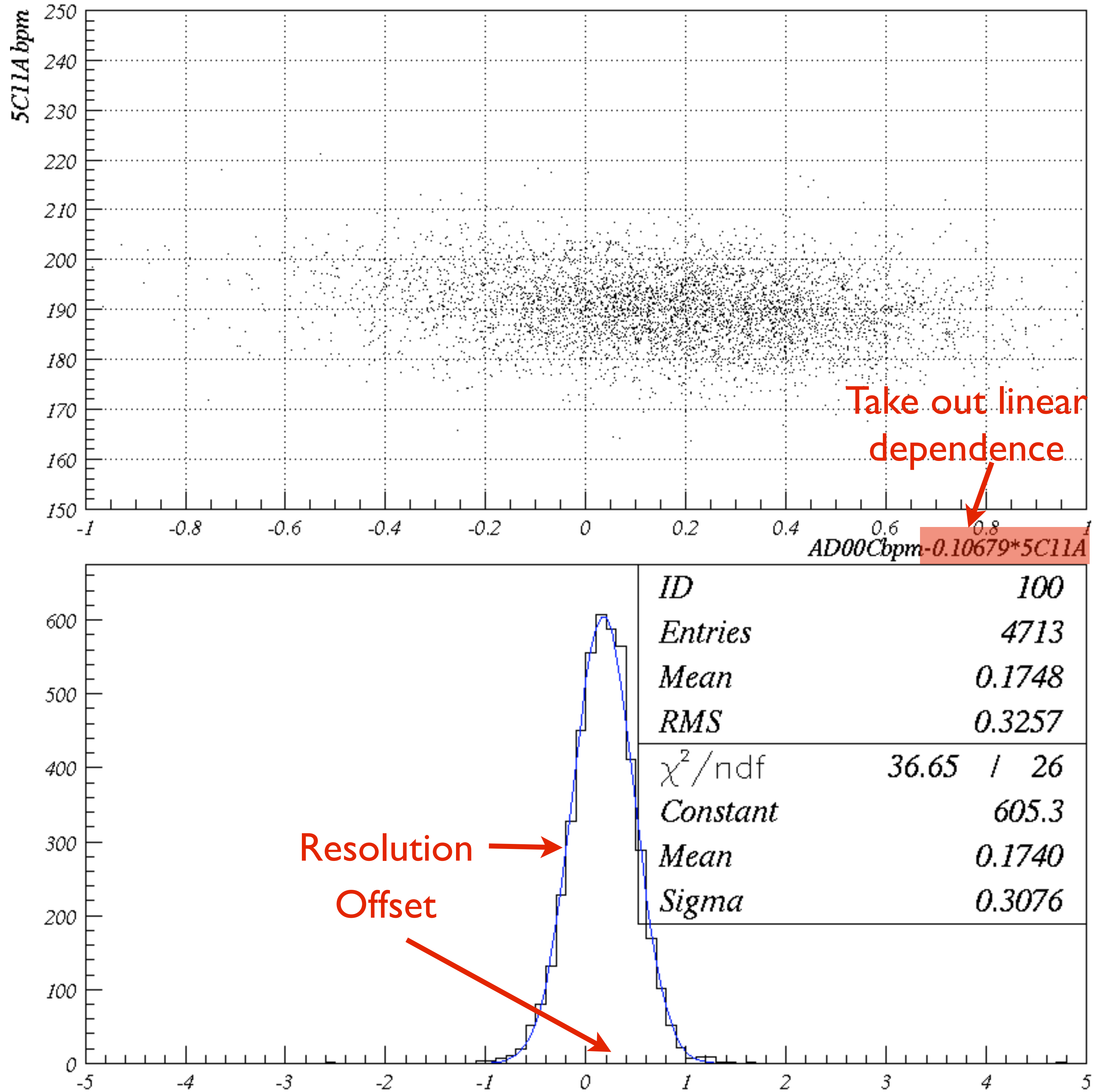
Large BPM offsets when Int. Mon. involved (50 nA typically).

Int. Mon. non linearity?

Jefferson Lab
Thomas Jefferson National Accelerator Facility
Exploring the Nature of Matter

Accuracy of current monitors

Verification of the normalization and accuracy of the current:



Accuracy of current monitors

Data: 04/11/16 18:00 to 04/12/16 6:00am

correlation y vs x	width/current (from RMS /from fit sigma)	slope y/x	offset (from dist./from fit) in nA
5C11B vs AD00C BCM	9.45% / 9.22%	1.012	4.1E-2 / 8.1E-2
AD00 BPM vs AD00C BCM	9.40% / 9.28%	0.103	4.9E-2 / -4.0E-2
5C11 vs AD00C BCM	9.47% / 9.22%	0.989	1.1E-1 / -1.7E-2
5C11A vs AD00C BCM	9.32% / 8.92%	0.967	5.8E-3 / -1.2E-4
AD00 vs AD00C BCM	9.33% / 8.93%	0.970	7.0E-3 / -6.2E-3
5C11 vs AD00C BPM tight correlation	0.13% / 0.13%	9.57	4.7E-2 / -5.3E-3
5C11 vs AD00C BPM medium correlation	0.63% / 0.63%	9.57	-1.1E-2 / -6.9E-3
5C11 vs AD00C BPM broader correlation	2.26% / 1.45%	9.57	-9.8E-3 / 8.8E-4
5C11A vs AD00C BPM	1.72% / 1.57%	9.36	-2.8E-3 / 1.6E-3
5C11B vs AD00C BPM (tighter correlation)	0.25% / 0.23%	9.81	-1.6E-3 / -2 E-3
5C11B vs AD00C BPM (broader correlation)	1.76% / 1.36%	9.81	1.3E-2 / 3.2E-3
AD00 vs AD00C BPM	1.72% / 1.57%	9.40	-5.0E-4 / 3.4E-3
5C11A vs 5C11	1.73% / 1.62%	0.978	2.6E-2 / 6.5E-2
AD00 vs 5C11	1.74% / 1.63%	0.981	-2.3E-1 / 2.3E-2
5C11B vs 5C11 (broader correlation)	1.62% / 1.25%	1.023	9.6E-2 / 6.7E-2
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5C11B vs 5C11A	1.67% / 1.56%	1.047	4.6E-2/2E-3
AD00 vs 5C11A	0.074% / 0.065%	1.014	1.671/1.672
AD00 vs 5C11B	1.86% / 1.38%	0.958	-1.05E-1/-4.82E-2

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Accuracy of current monitors

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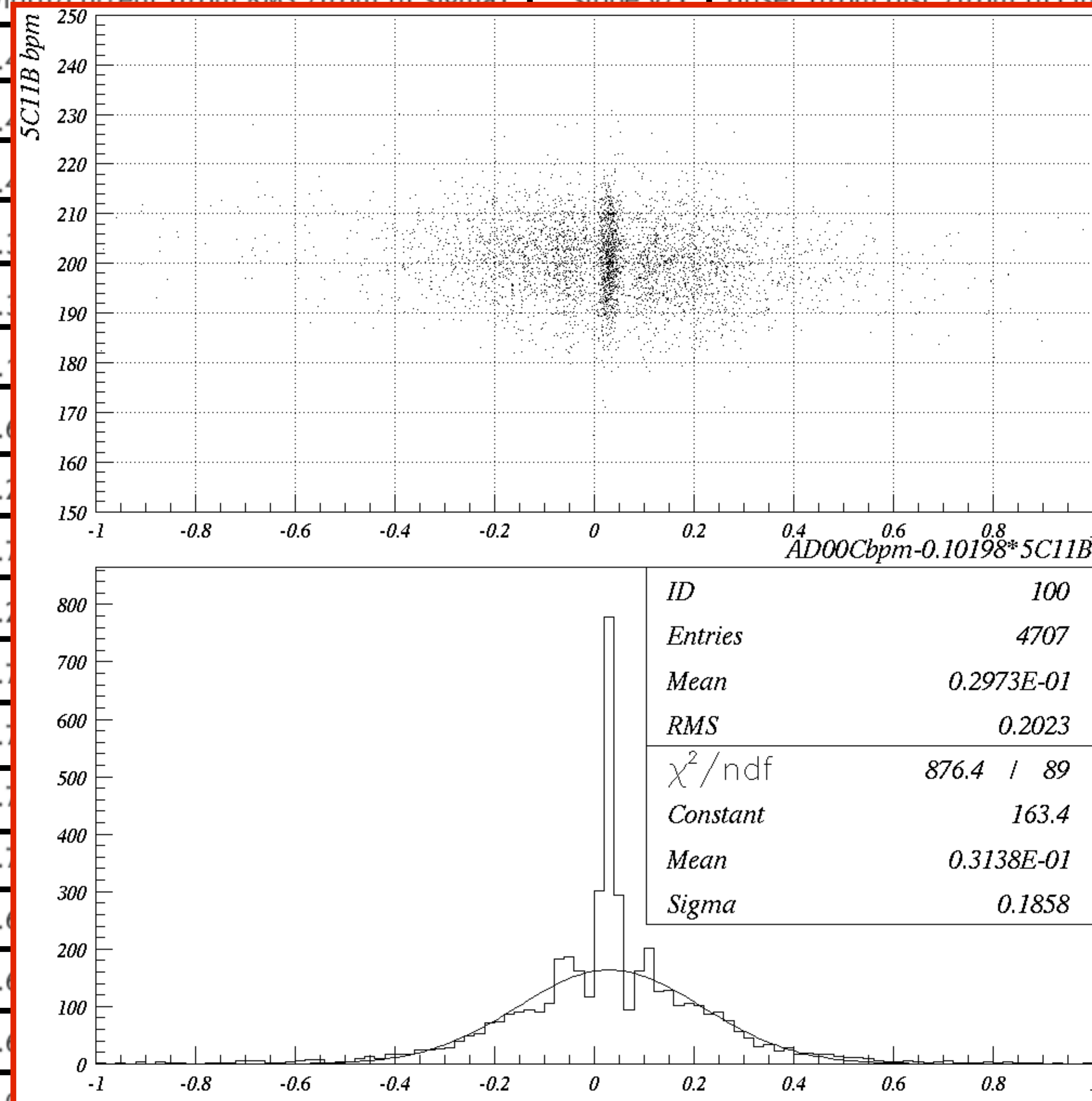
5C11B vs AD00C BCM	9.4		
AD00 BPM vs AD00C BCM	9.4		
5C11 vs AD00C BCM	9.4		
5C11A vs AD00C BCM	9.1		
AD00 vs AD00C BCM	9.1		
5C11 vs AD00C BPM tight correlation	0.1		
5C11 vs AD00C BPM medium correlation	0.6		
5C11 vs AD00C BPM broader correlation	2.2		
5C11A vs AD00C BPM	1.7		
5C11B vs AD00C BPM (tighter correlation)	0.2		
5C11B vs AD00C BPM (broader correlation)	1.7		
AD00 vs AD00C BPM	1.7		
5C11A vs 5C11	1.7		
AD00 vs 5C11	1.7		
5C11B vs 5C11 (broader correlation)	1.6		
5C11B vs 5C11 (broader correlation)	1.6		
5C11B vs 5C11A	1.6		
AD00 vs 5C11A	0.0		
AD00 vs 5C11B	1.86% / 1.38%	0.958	-1.05E-1/-4.82E-2



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Accuracy of current monitors

Data: 04/11/16 18:00 to 04/12/16 6:00am

Cross-calibration: good within 5% (apart for AD00C BPM which is not calibrated)

Resolutions: within 2% except for AD00C BCM which is ~9.3%

Multiple peaks seen in some cases (AD00C vs 5C11, AD00C vs 5C11B, 5C11b vs 5C11)

BCM jitter

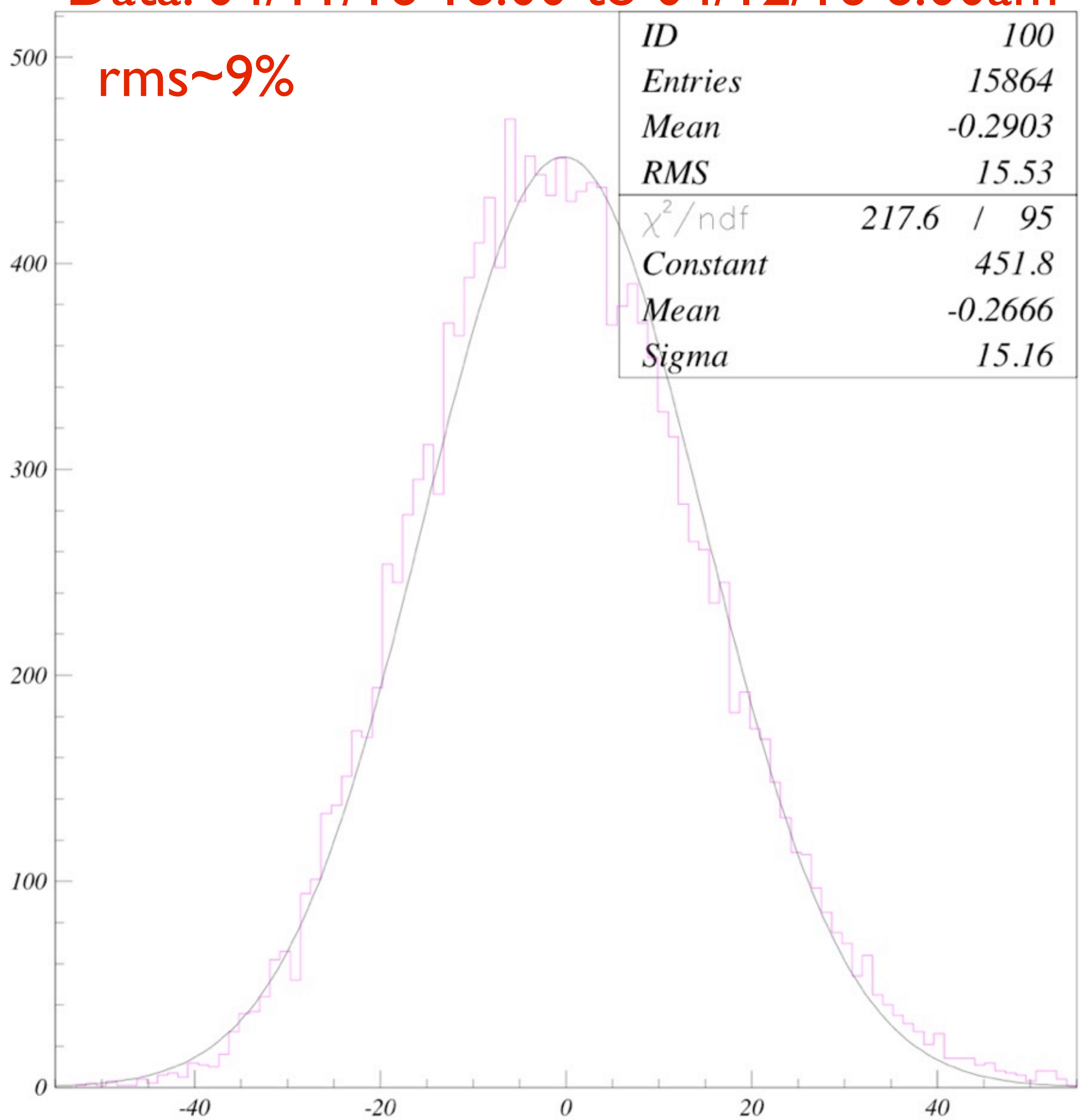
Trent Allison: Larger jitter seen on BCM is real. Not due to electronics. Only device seeing it due to high-bandwidth capacity. Other Hall D beam line devices for current monitoring (BPM) filter out the jitter.

Origins of the jitter:

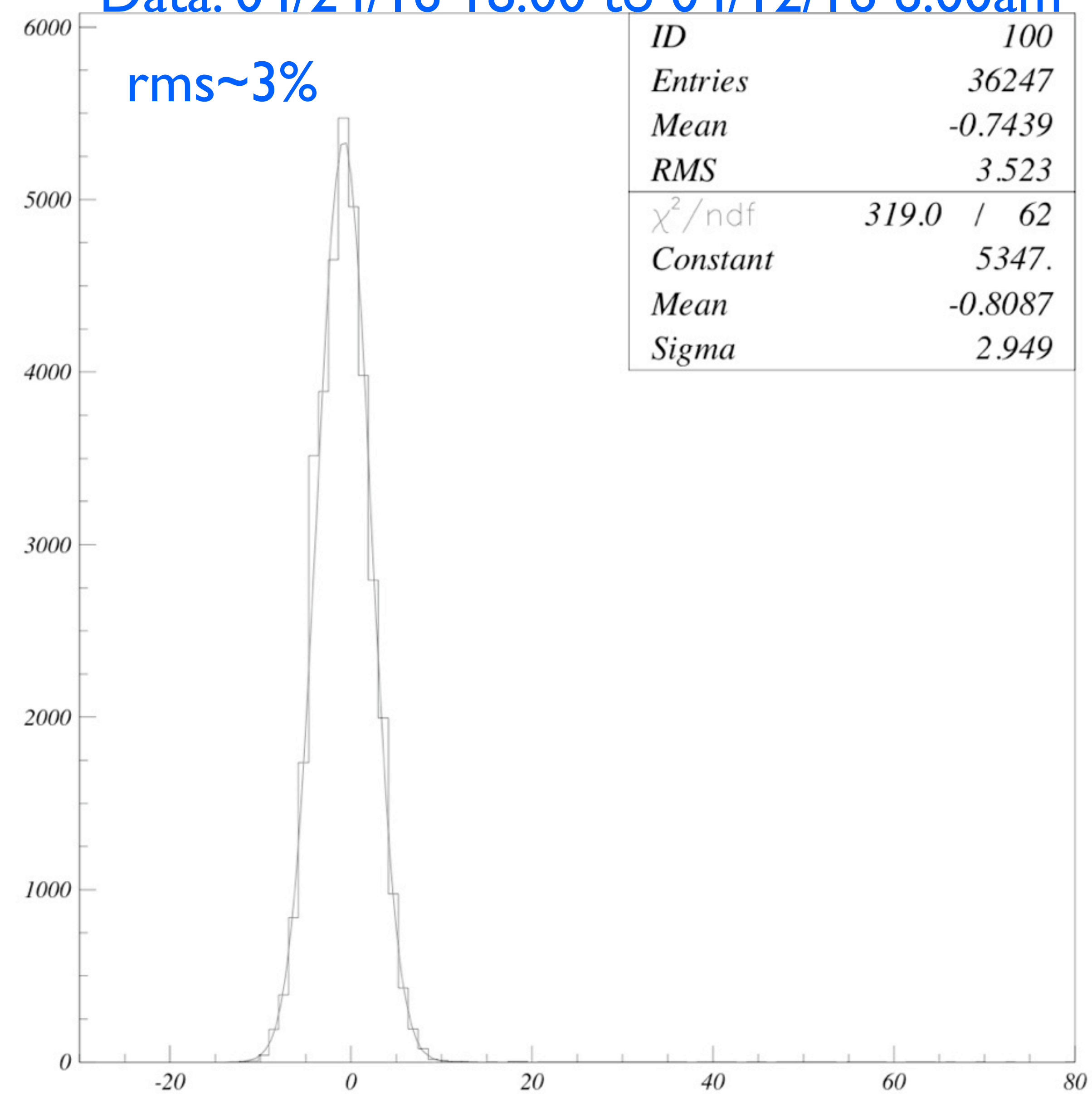
- 10-20 kHz noise from injector
- 1.3 kHz of uncertain origin. Sometime absent
- 60 and 120 Hz fluctuations (largest contributor), usually linked to beam scrapping
- 0.3 Hz current lock feedback
- ...

Depends on time:

Data: 04/11/16 18:00 to 04/12/16 6:00am



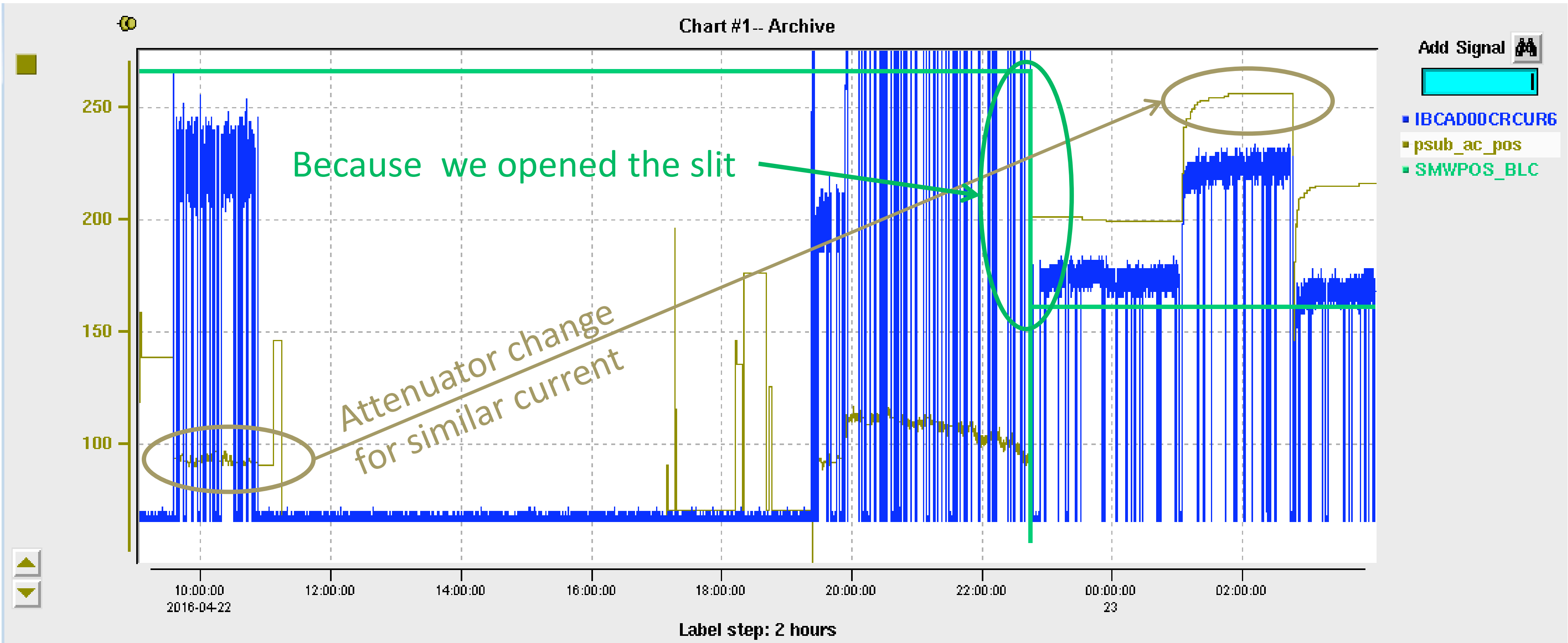
Data: 04/24/16 18:00 to 04/12/16 6:00am



BCM jitter

After talk addendum: Trent Allison conducted some more studies: It appears that the RMS went down on the 24th because the slit (SMWPOS_BLC) was opened wider (while the attenuator PSUB_ac_pos was lowered). Consequently, there was much less scrapping on the slit and that stabilized the current. See Trent Allison's slide below.

(A larger value of SMWPOS_BLC means less opening, and a larger value of PSUB_ac_pos means more attenuation).



The laser attenuator setting (gold) in the Injector is a rough measure of the beam current at the very beginning of the machine. Ops opened the slit (green) probably because they were running out of room on the attenuator. That changed the attenuator setting drastically and stopped the beam from scrapping on the slit. The reduction of scraping on the slit is what helped stabilize the current.

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