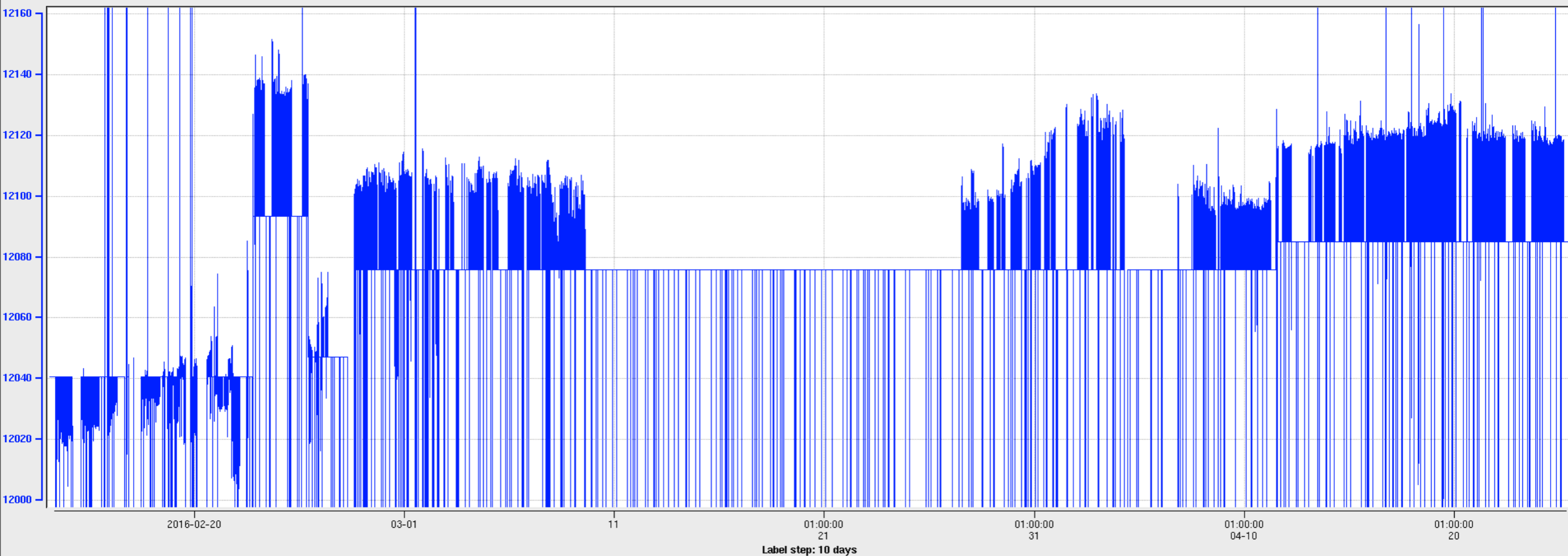


Hall D beam energy during the spring 2016 run

A. Deur

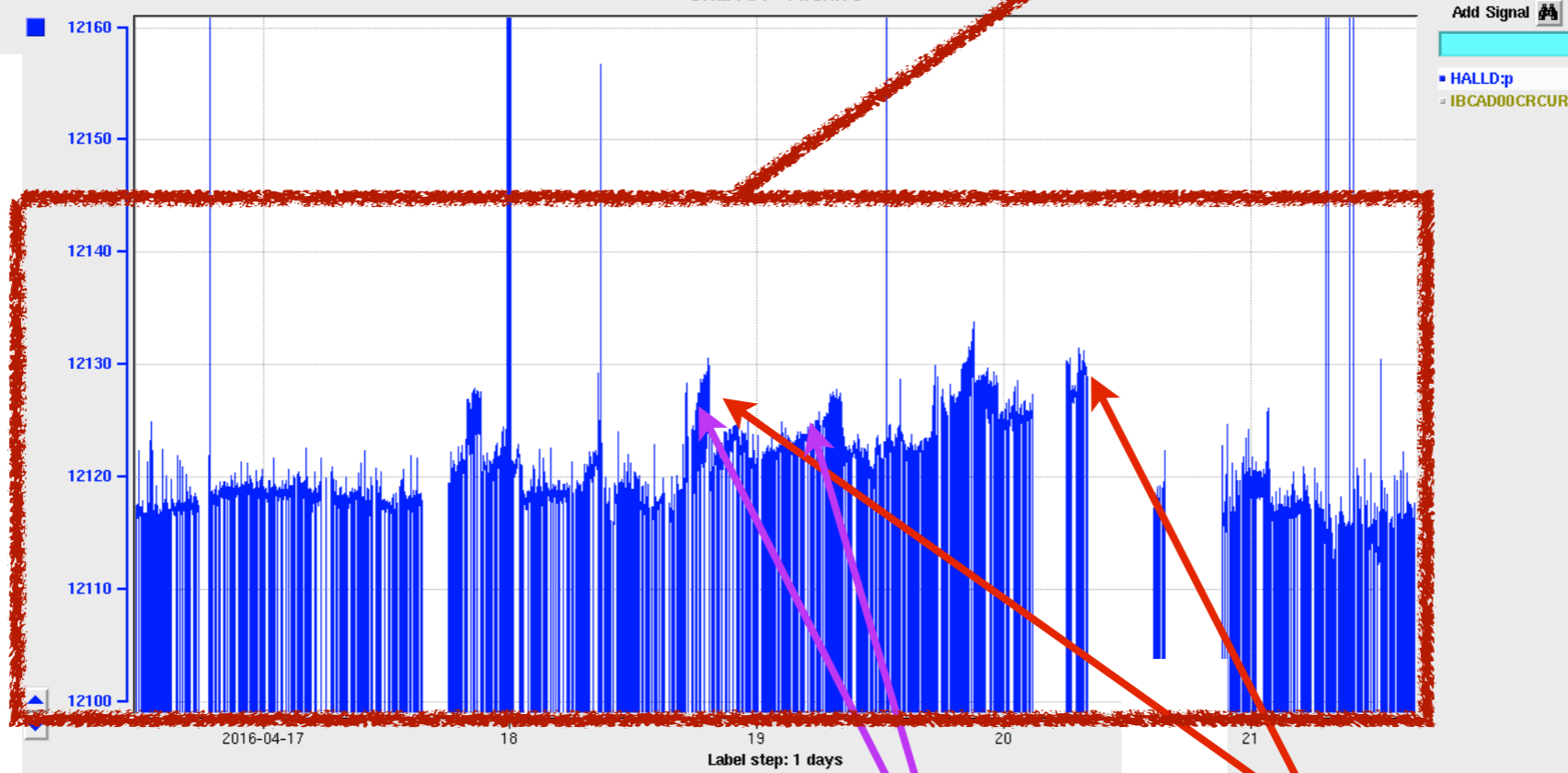
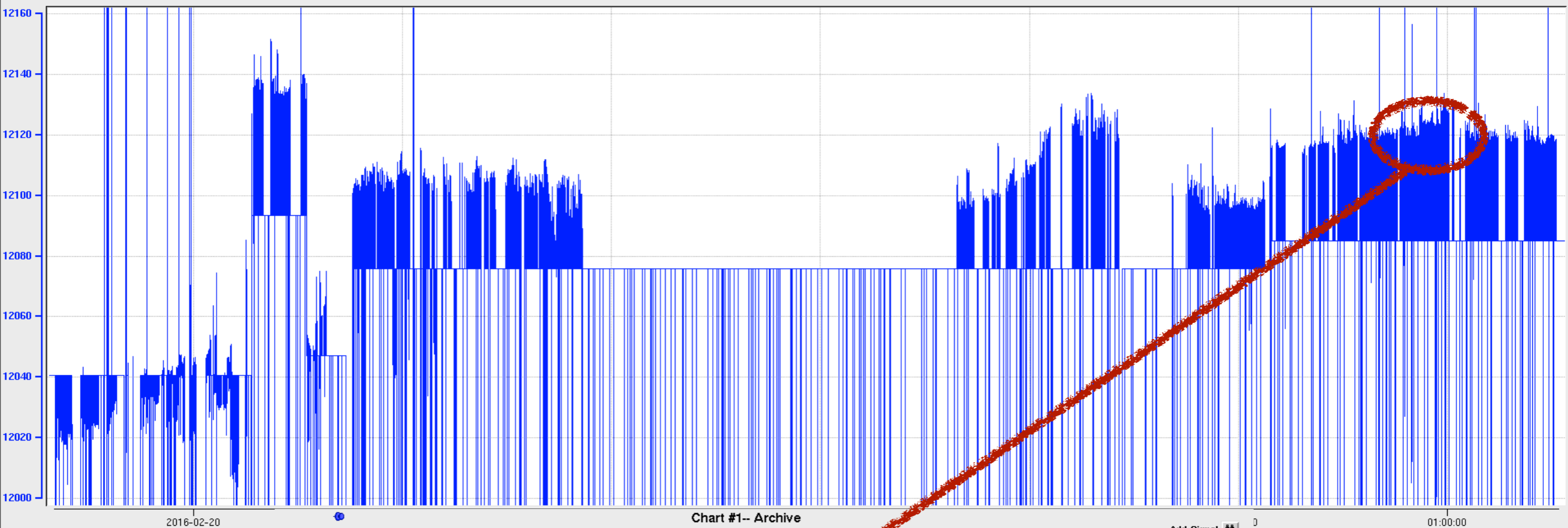
Beam energy stability



Uncorrected Hall D beam energy from MyaViewer.

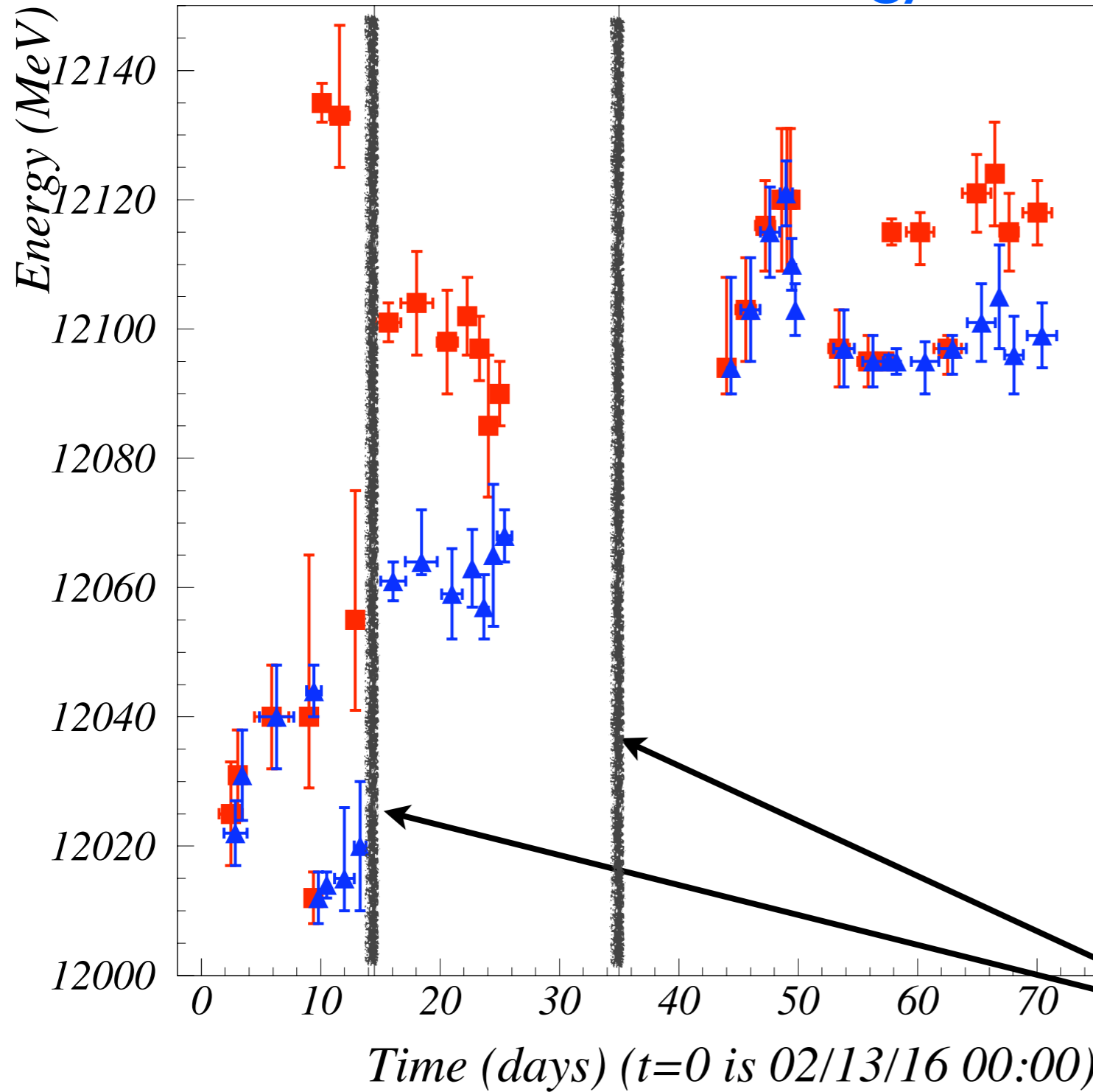
- Obtained via **beam displacement in Hall D ramp** (epics name: HALLD:p).
- **Large energy variations** (up to 140 MeV).
- Some energy variations are **genuine**. Others are measurement **artifacts**.
- Sometimes **hard to decide if variation is real**.
- **Mystery correlations** remain to be explained.
- Because of artifacts, HALLD:p cannot be used on (epics) event-per-event basis.

Beam energy stability



Energy time dependence exhibits both **slow drifts** and **jumps**.

Beam energy stability



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

- Uncorrected Hall D beam energy
- ▲ Corrected for artificial drifts

error bars bracket the time range or energy drift range. (They are not uncertainties.)

Possible offsets after significant beam interruptions.

Beam energy stability

error bars bracket the time range or energy drift range. (They are not uncertainties.)

Time (start, end)	energy (HALLD:p) (MeV) (uncorrected)	energy (corrected)	offset (MeV)	Notes
02/13 13:00 02/15 11:00	12025±8	12022±5	0	True drifts by -5 MeV during the first 10h. 5 MeV spikes at $t = 13.7h$ are real. Other changes are artifacts.
02/15 17:00 02/16 8:30	12031±7	12031±7	0	02/16: 0:00 to 8:30am: Continuous +13MeV up drift is probably real.
02/17 11:00 02/20 8:00	12040±8	12040±8	0	Many energy drifts and jumps. Most as presumably real.
02/20 14:00 02/22 4:19	12040± $_{10}^{25}$ $t < 30h$ 12012±4 $t > 30h$	12044±4 12012±4	0	The jumps from 12050 to 12033 MeV at $t \simeq 11h$ and from 12032 to 12040 MeV are artifacts. The jump from 12039 to 12012 MeV is real.
02/22 20:00 02/23 8:30	12135±3	12014±2	-120 -118	Beam down for 16h. Came back at 12133 MeV. Hall A pass change (now 1 pass) occurred after 120 MeV jump.
02/23 18:00 02/25 10:00	12133± $_{7}^{14}$	12015± $_{7}^{14}$	-118	
02/25 10:00 02/26 9:00	12055± $_{14}^{20}$	12020±10	-35	Artificial -83 MeV jump on 02/25 at 10:17am. Artif. jump of +12 MeV at the end of the period.
02/27 15:00 02/29 16:35	12101±3	12061±3	-13 -40	Beam was down for 30h. Came back with a +27 MeV offset. Can't assess if real. We arbitrarily assume for now that it is real. There is a -60 MeV shift the last few hours, then back.
02/29 17:00 03/01 9:00	12104±8	12064± $_{2}^{8}$	-34	Genuine +13 MeV drift at the start. Artificial -6 GeV shift at the end.
03/02 18:00 03/05 10:55	12098±8	12059±7	-39	Artif. +5 MeV jump.
03/05 20:10 03/06 16:10	12102±6	12063±6	-39	+5 MeV jump for 2h.
03/06 20:00 03/07 18:00	12097±5	12057±5	-36	Should add +3 MeV for $t > 19h$.
03/07 18:00 03/08 9:00	12085±11	12065±11	-20	Two energy jumps. 1st one (16 MeV) is an artifact. 2nd one appears real.
03/08 9:00 03/09 14:40	12090±5	12068±4	-18	Apparently genuine 15 MeV jump occurred between previous period and this one
03/27 13:00 03/28 9:41	12094± $_{3}^{14}$	12094± $_{3}^{14}$	≡ 0	18 days down time \implies cannot relate energy scale of this period to previous one \implies Offset set to 0 arbitrarily. Genuine drift of 17 MeV up and then down.
03/28 19:10 03/30 10:10	12103±8	12103±8	-1	Genuine drift of 16 MeV. +1 MeV artif. jump in middle of period.

Beam energy stability

error bars bracket the time range or energy drift range. (They are not uncertainties.)

Time (start, end)	energy (HALLD:p) (MeV) (uncorrected)	energy (corrected)	offset (MeV)	
03/30 10:10 04/01 1:10	12116±7	12115±7	-1	Genuine drift of 13 MeV.
04/02 1:50 04/04 7:50	12120±11 <i>t</i> < 25h 12120±11 25 < <i>t</i> < 47h 12120±11 <i>t</i> > 47h	12121±5 12110±4 12103±4	-8	Large energy fluctuation (20 MeV) appears real apart for a +17 MeV offset.
04/07 14:00 04/09 8:00	12097±6	12097±6	0	Beam down for 3 days. Came back at 12096 MeV. Unclear if the -8 MeV shift between this period and previous one is real. We arbitrarily assume so.
04/09 8:00 04/11 00:00	12095±4	12095±4	0	
04/11 00:00 04/12 7:00	12095±1 <i>t</i> < 9h 12115±2 <i>t</i> > 9h	12095±1 12095±2	0 -20	Beam down for 6h. Came back at 12115 MeV. The change seems to be due to a re-tune after a Hall A pass change. The shift seems to be an artifact.
04/13 1:50 04/15 8:50	12115± $\frac{3}{5}$	12095± $\frac{3}{5}$	-20	
04/15 8:50 04/17 15:26	12097± $\frac{2}{3}$	12097± $\frac{2}{3}$	-20	
04/17 18:00 04/20 2:50	12121±6	12101±6	-19	Beam went down on 04/17 15:23. Came back at 12121 MeV, less stable, with overall systematic up drift and many artif. spikes.
04/20 6:00 04/20 16:00	12124±8	12105±8	-19	Real +4 MeV jump between this period and previous one, after 4h15 down time.
04/20 21:00 04/22 11:00	12115±6	12096±6	-19	Two artif. +5 MeV jumps at <i>t</i> ≈ 3h and <i>t</i> ≈ 23h
04/22 19:10 04/25 6:06	12118±5	12099±5	-19	

Real energy variations

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

Real drifts (typically a few MeV, at worst 10 MeV) **criteria** :

- Correlate with **x-position** (and not y) of the beam **after tagger magnet** (AD00c BPM in the beam dump).
- Correlate with **dispersive** Hall D ramp BPM **5C02-y** (but not x) and not with non-dispersive BPM 5C08-y.
- Correlate with ARC energies and possibly Hall A energy change.

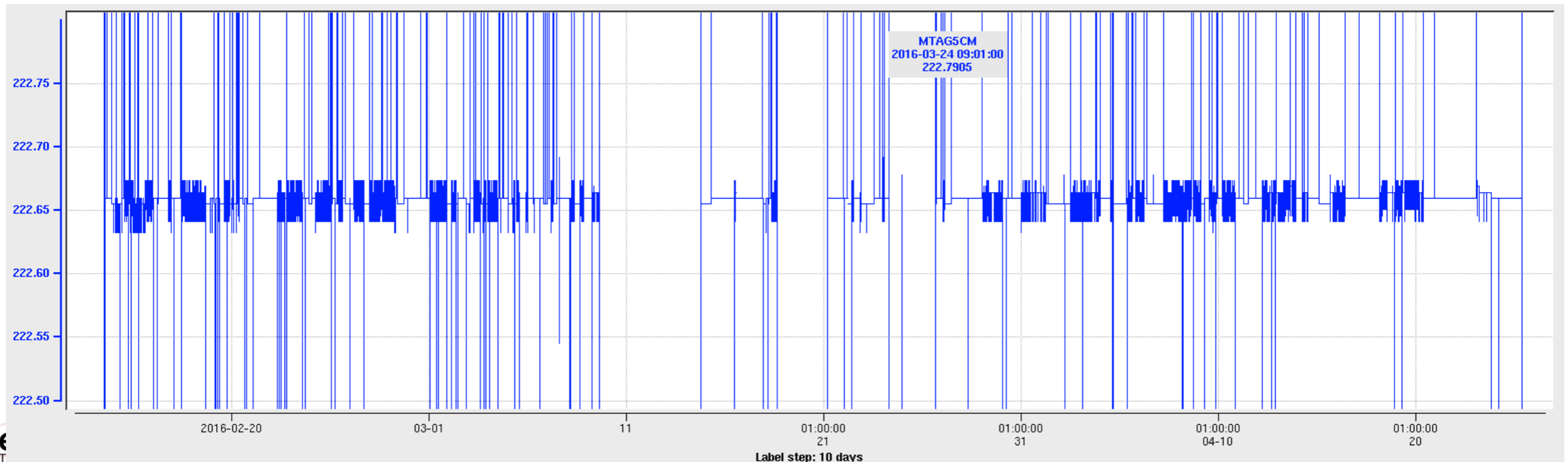
Real energy variations

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- Correlate with **dispersive** Hall D ramp BPM **5C02-y** (but not x) and not with non-dispersive BPM 5C08-y.
- Correlate with ARC energies and possibly Hall A energy change.

Good diagnostic: tagger field was very stable during entire run:



Real energy variations

Energy is measured from the beam

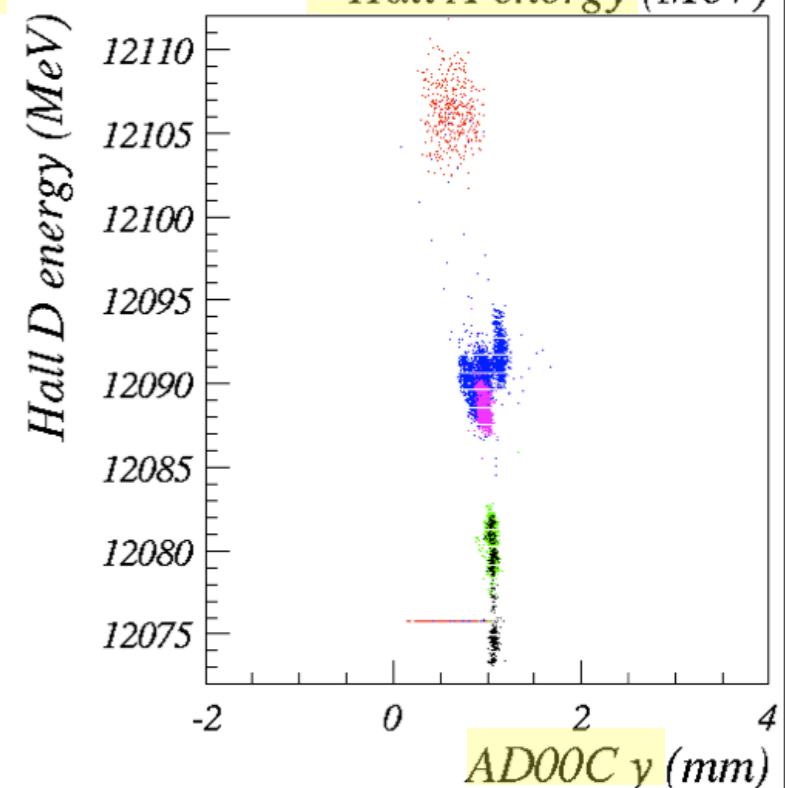
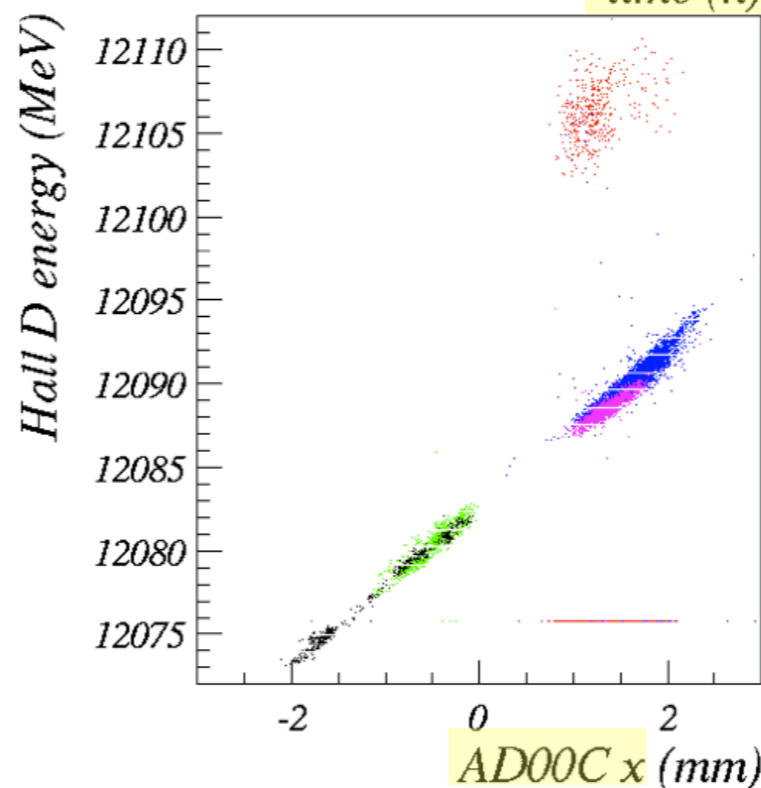
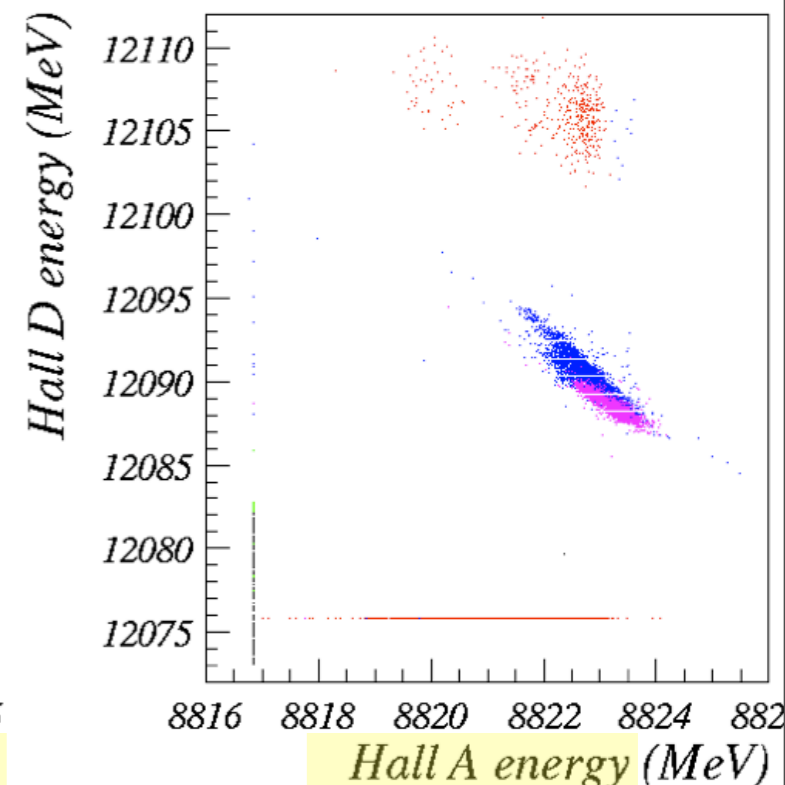
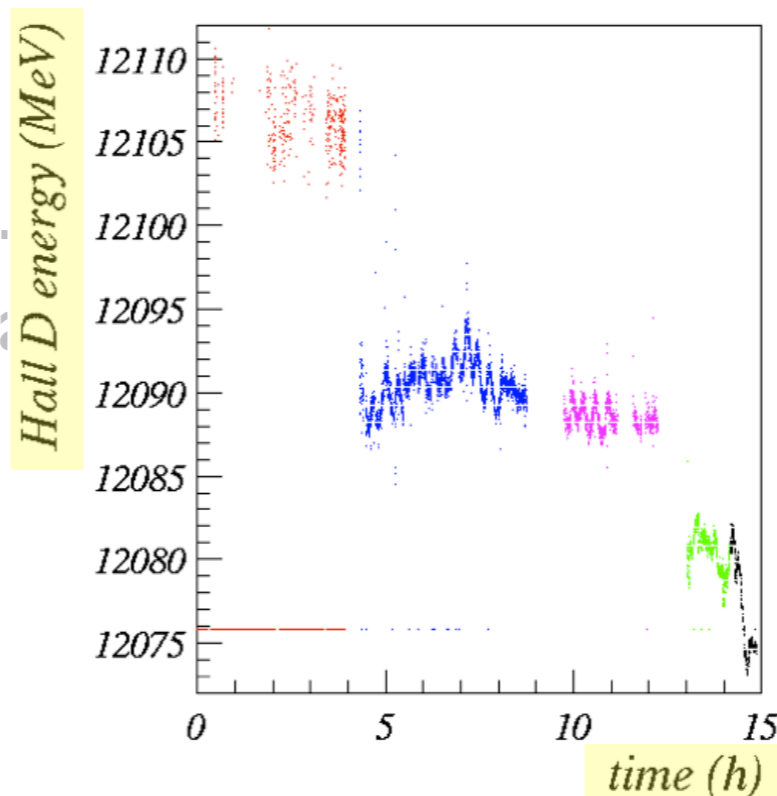
Real drifts (typically a few MeV, at worst 10

- Correlate with **x-position** (and not **y**) of the beam after tagger magnet

(AD00c BPM in the beam dump).

- Correlate with dispersive Hall D with non-dispersive BPM 5C08.

- Correlate with ARC energies: possibly Hall A energy change



Ex. data from Mar 6th - March 7th

Real energy variations

Energy is measured from the beam

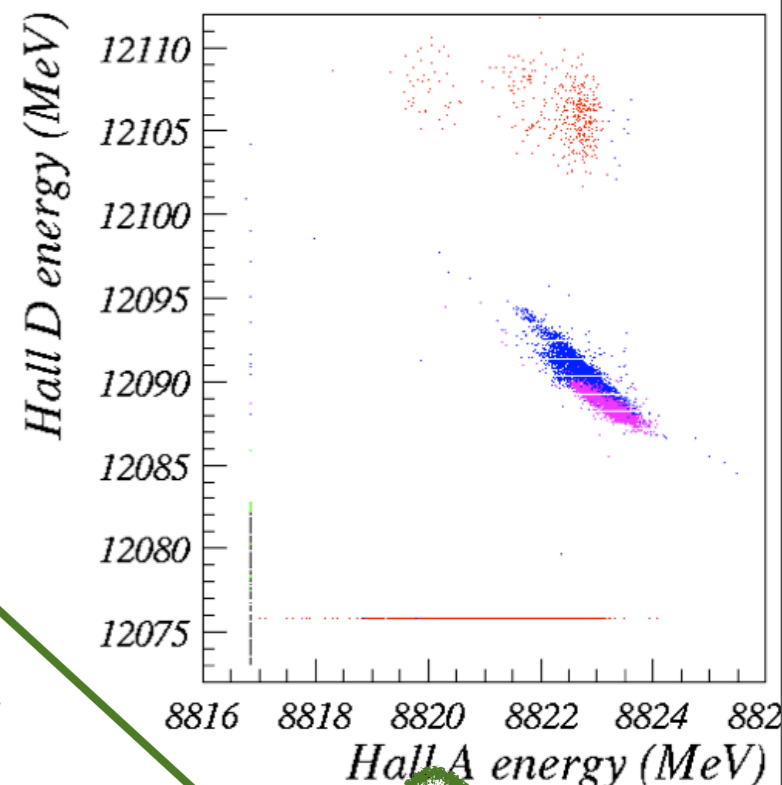
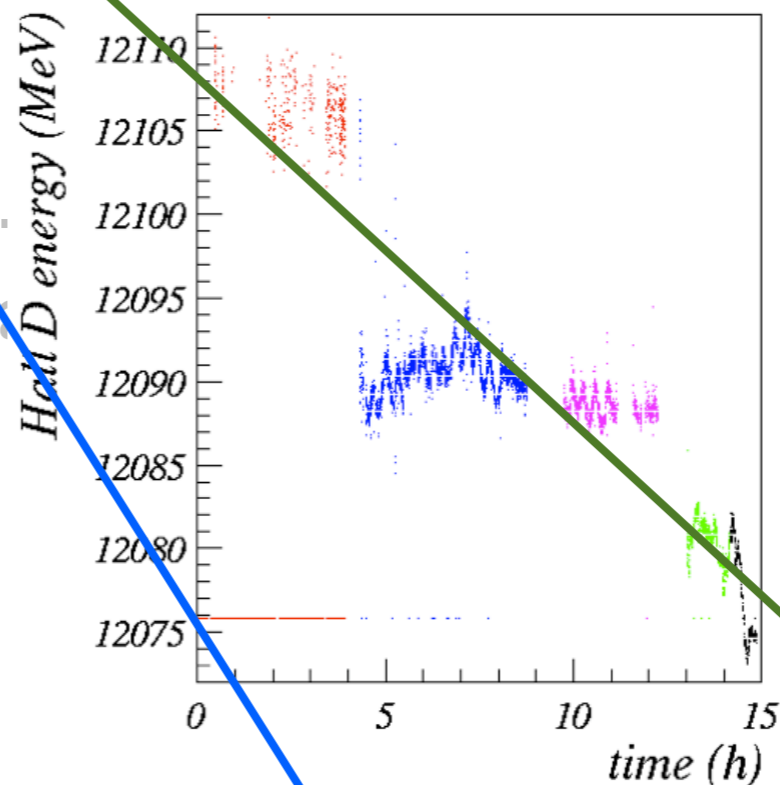
Real drifts (typically a few MeV, at worst 10

- Correlate with **x-position** (and not y) of the beam after tagger magnet

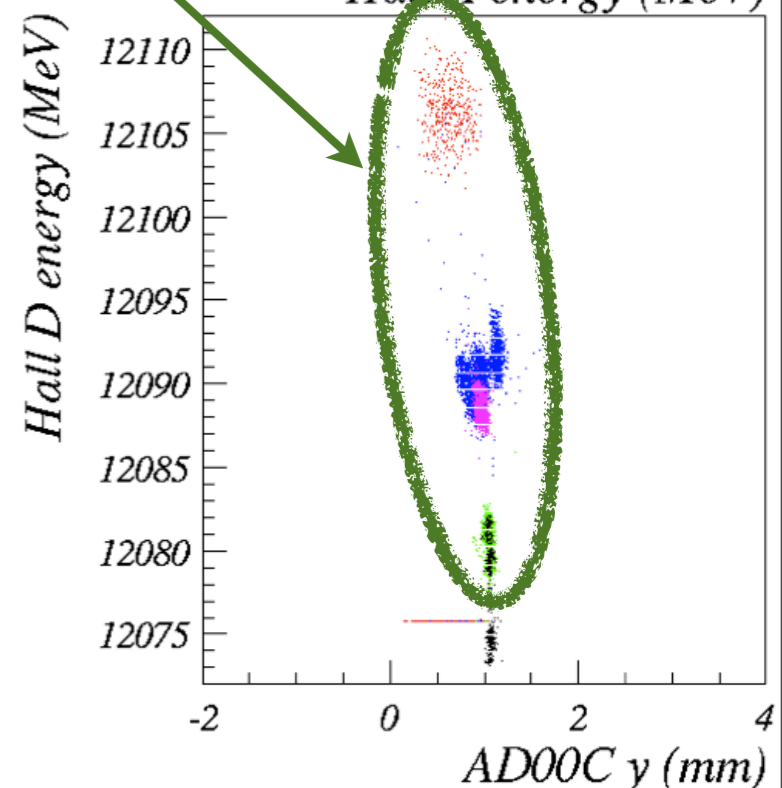
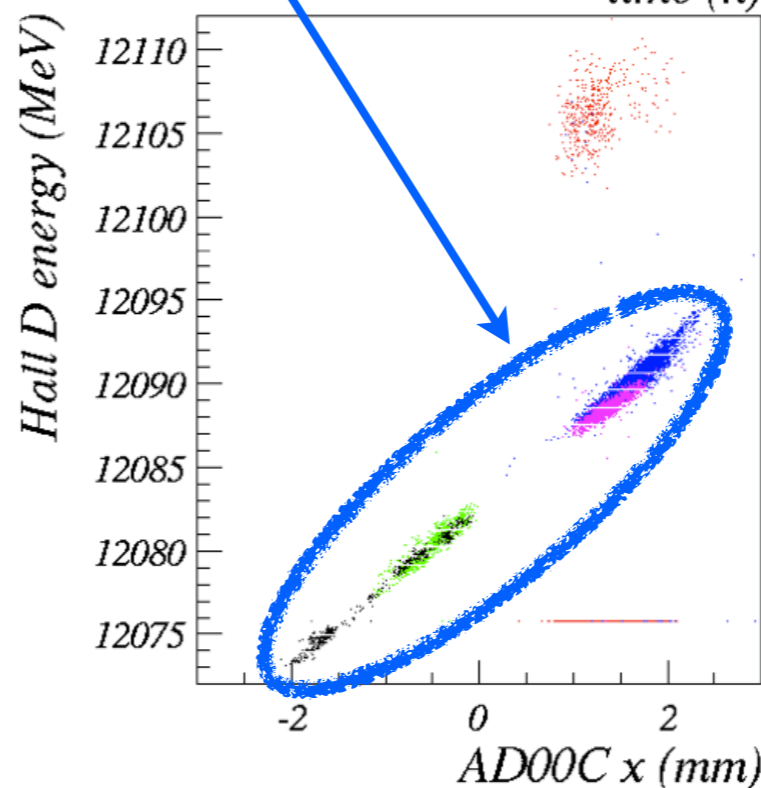
(AD00c BPM in the beam dump).

- Correlate with dispersive Hall D with non-dispersive BPM 5C08.

- Correlate with ARC energies, possibly Hall A energy change



Ex. data from Mar 6th - March 7th

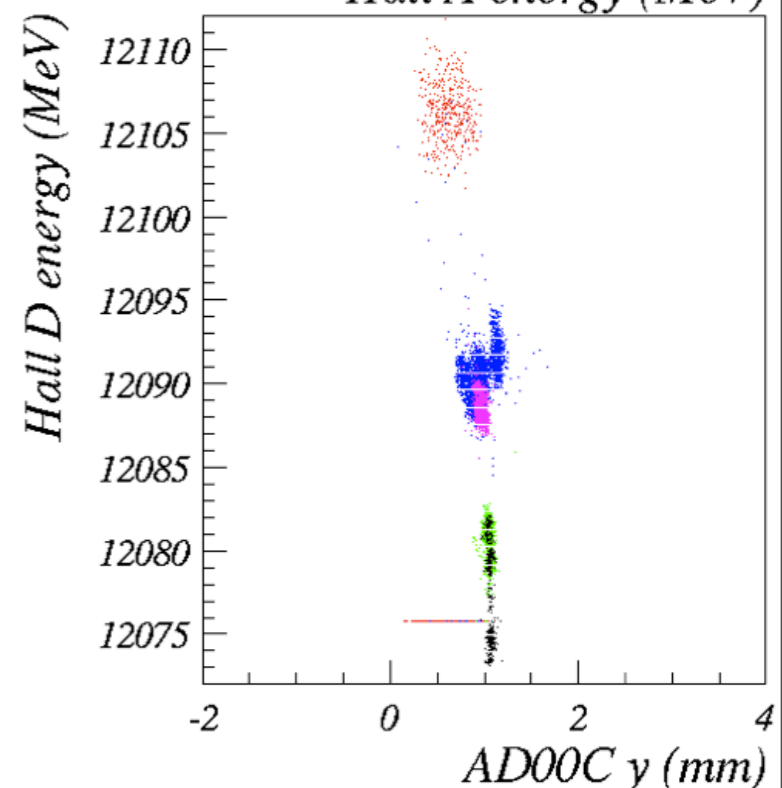
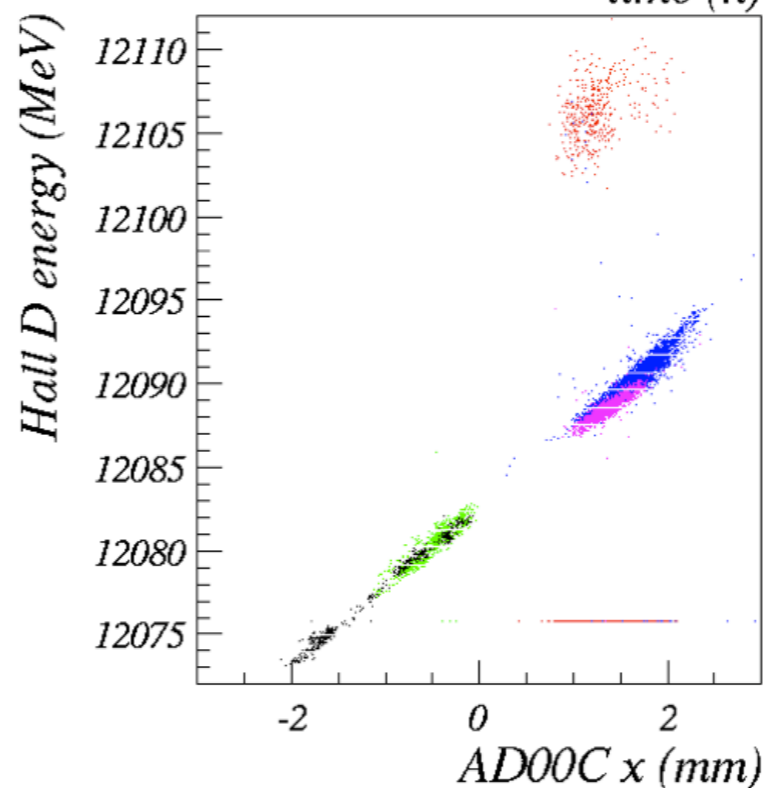
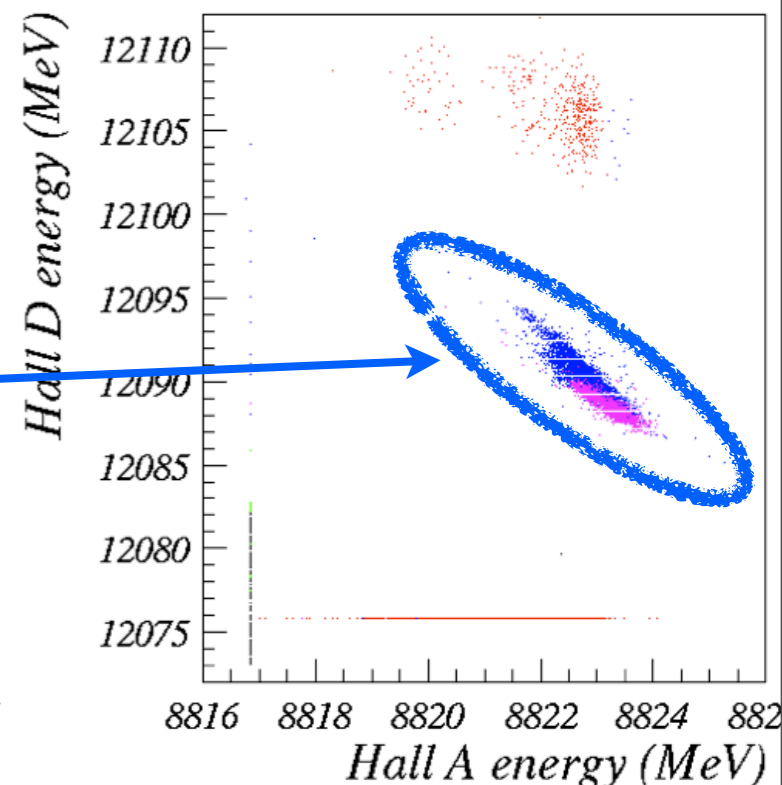
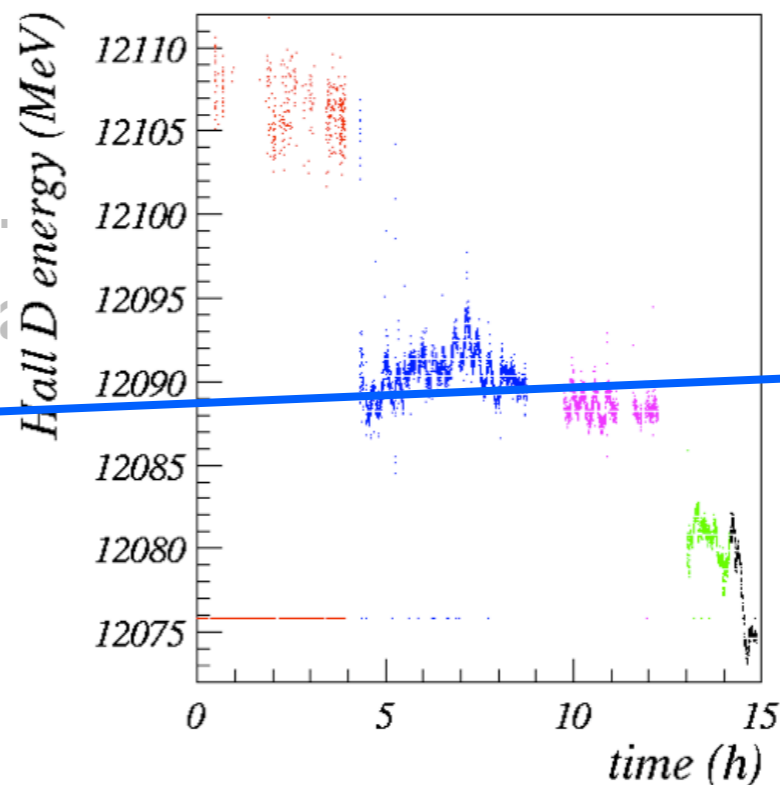


Real energy variations

Energy is measured from the beam

Real drifts (typically a few MeV, at worst 10

- Correlate with x-position (and not y) of the beam after tagger magnet (AD00c BPM in the beam dump).
- Correlate with dispersive Hall D with non-dispersive BPM 5C08.
- **Correlate with ARC energies**: possibly **Hall A energy** change

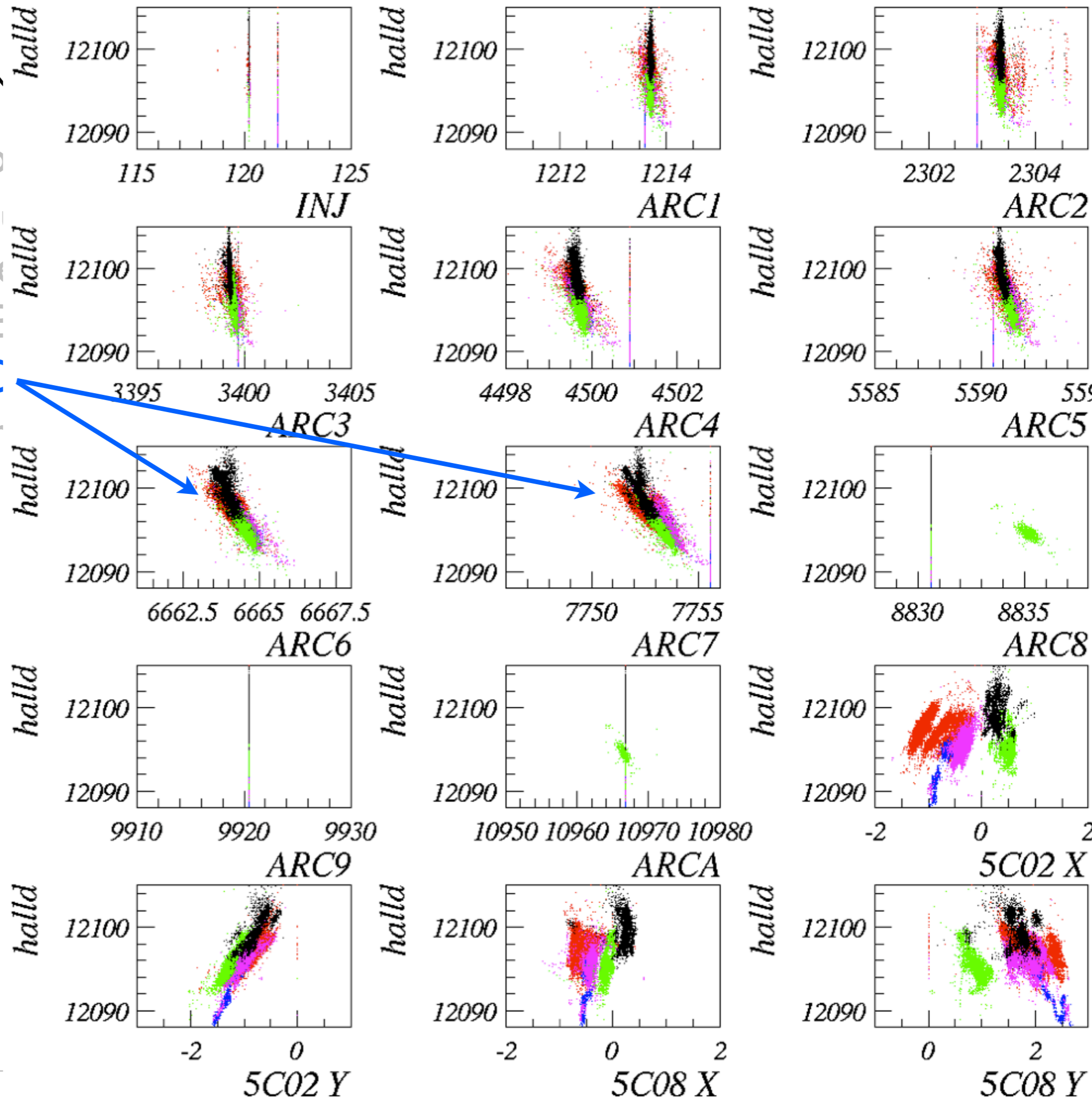


Ex. data from Mar 6th - March 7th

Real energy variations

Energy is measured from **Real drifts** (typically a few MHz)

- Correlate with x-positions (AD00c BPM in the beam drift)
- Correlate with dispersion with non-dispersive E
- **Correlate with ARC** possibly Hall A energy

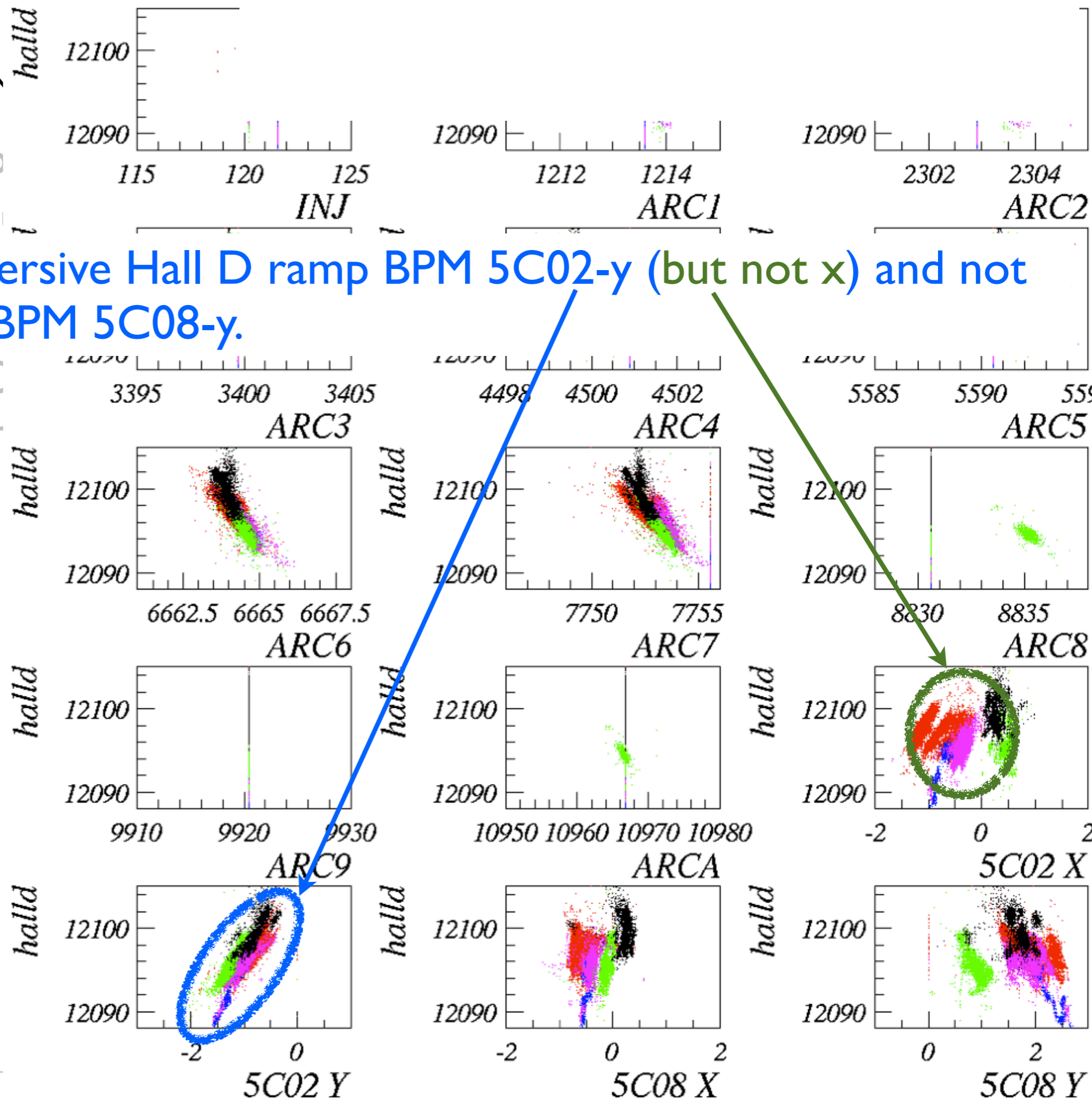


Ex. data from Mar 6th - March 7th

Real energy variations

Energy is measured from **Real drifts** (typically a few μ)

- Correlate with x-positions (AD00c BPM in the beam drift chamber)
- Correlate with dispersive Hall D ramp BPM 5C02-y (but not x) and not with non-dispersive BPM 5C08-y.
- Correlate with ARC positions (possibly Hall A energy)

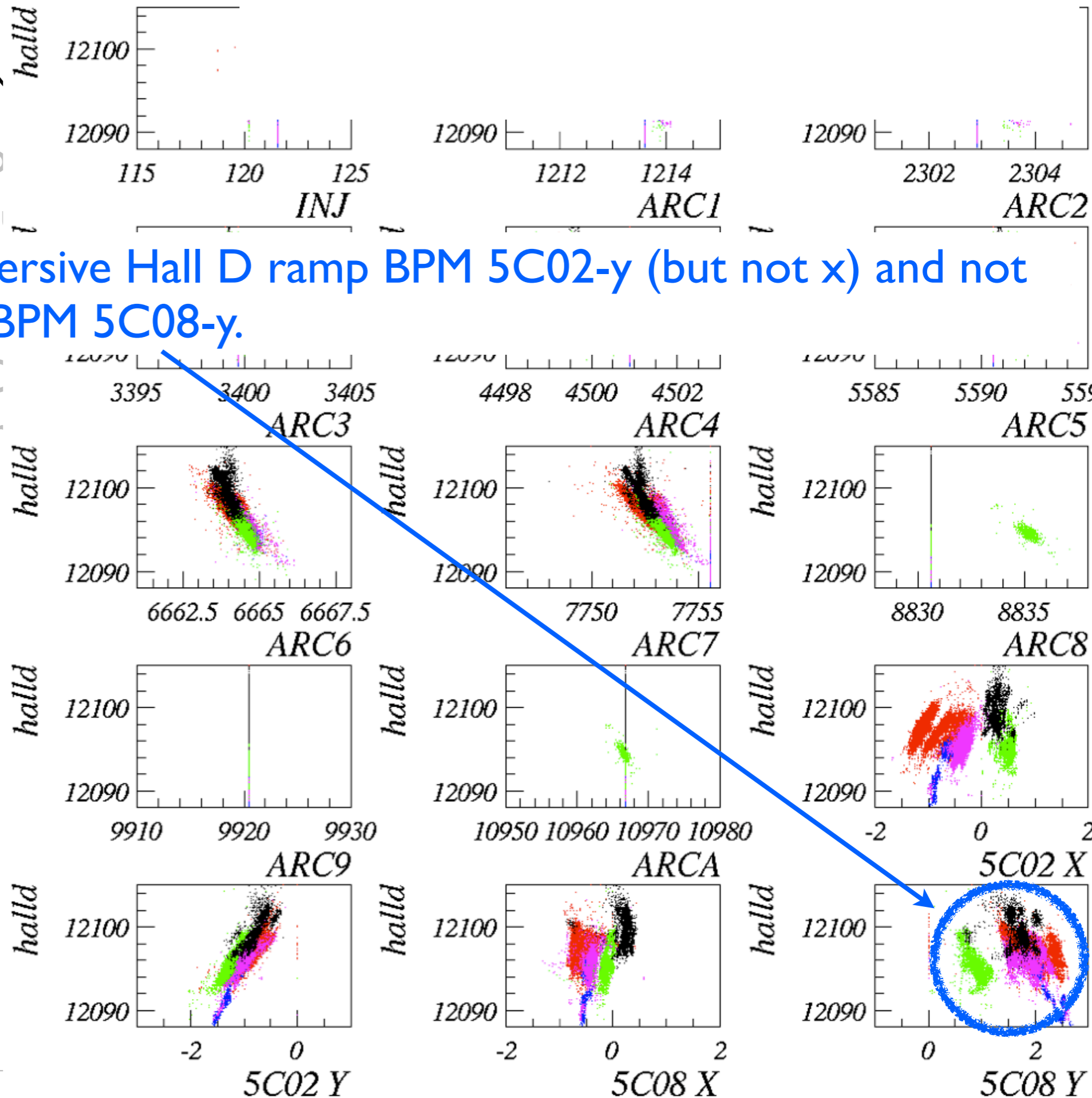


Ex. data from Mar 6th - March 7th

Real energy variations

Energy is measured from
Real drifts (typically a few μ)

- Correlate with x-positions (AD00c BPM in the beam drift chamber)
- Correlate with dispersive Hall D ramp BPM 5C02-y (but not x) and not with non-dispersive BPM 5C08-y.
- Correlate with ARC positions possibly Hall A energy



Ex. data from Mar 6th - March 7th

Real energy variations

Energy is measured from the beam

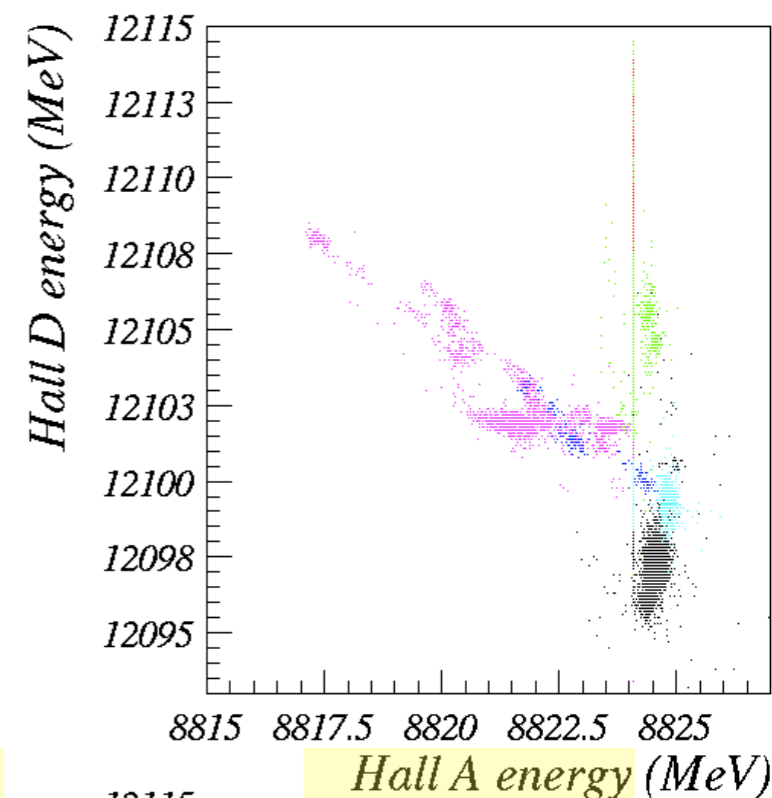
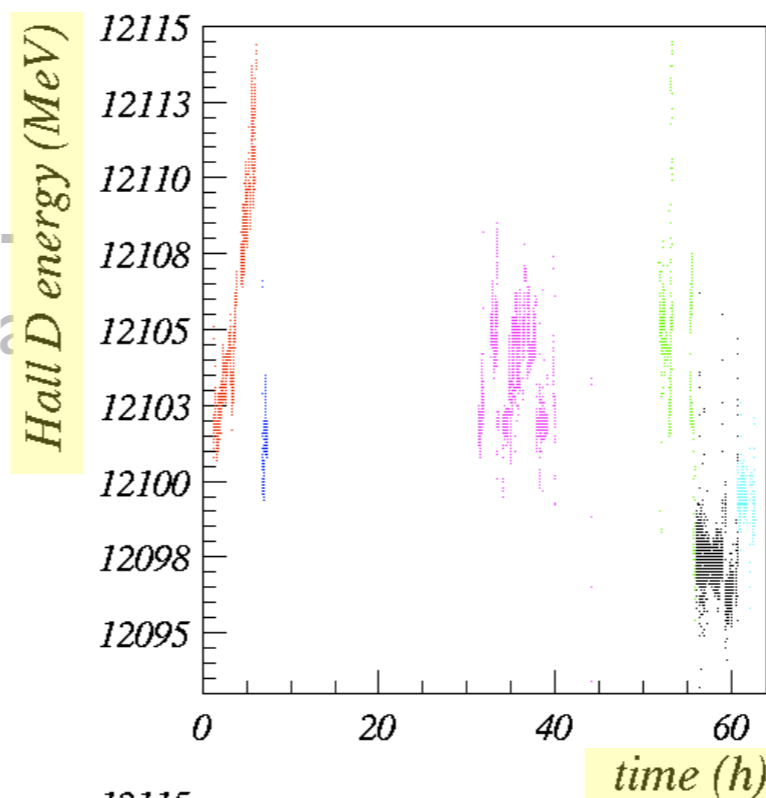
Real drifts (typically a few MeV, at worst 10

- Correlate with **x-position** (and not **y**) of the beam after tagger magnet

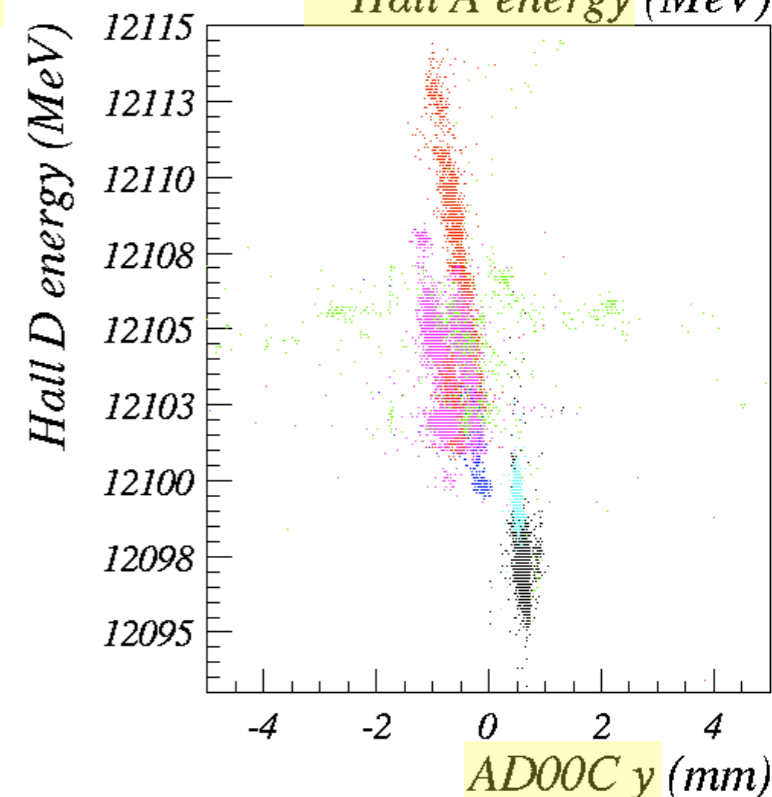
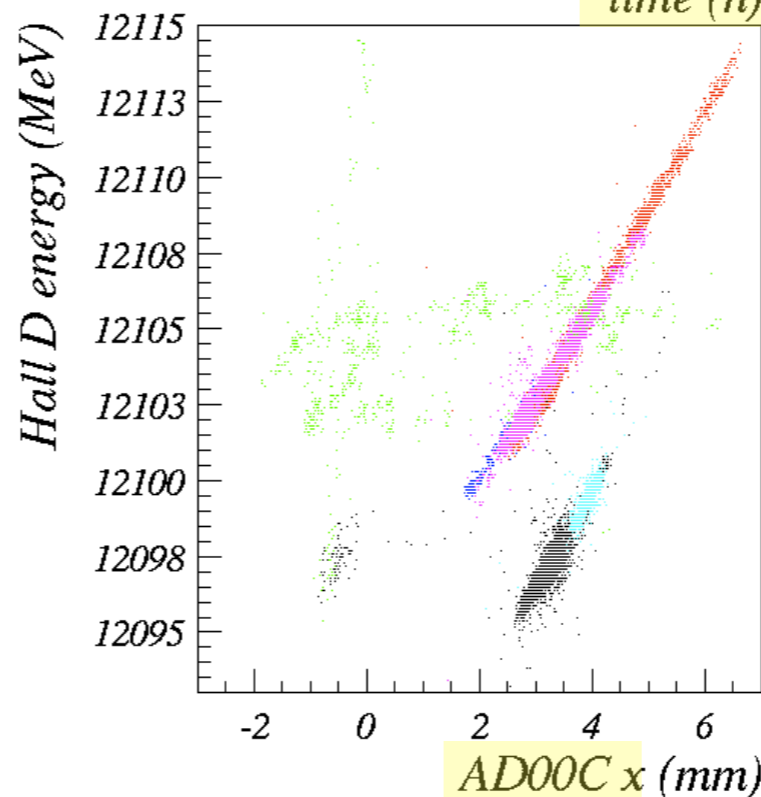
(AD00c BPM in the beam dump).

- Correlate with dispersive Hall D with non-dispersive BPM 5C08-

- Correlate with ARC energies and possibly Hall A energy change



Other Ex.: data from Feb. 29th - March 03



Real energy variations

Energy is measured from the beam

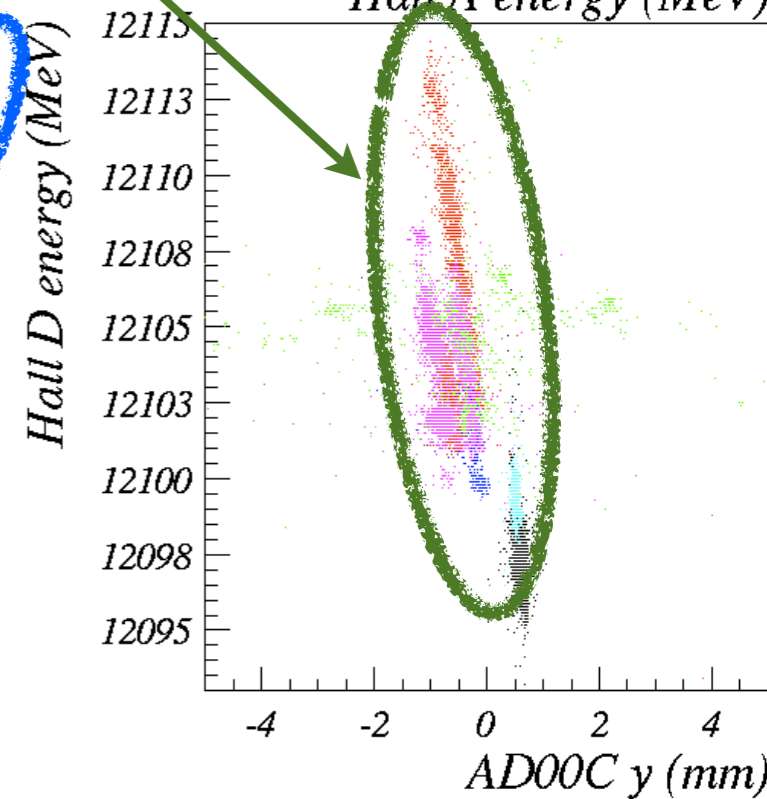
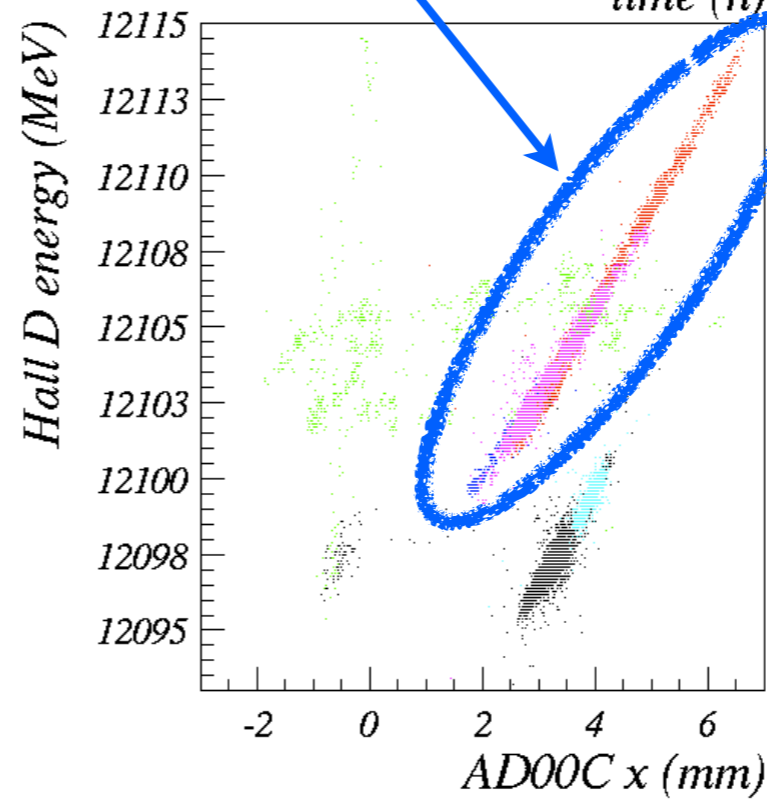
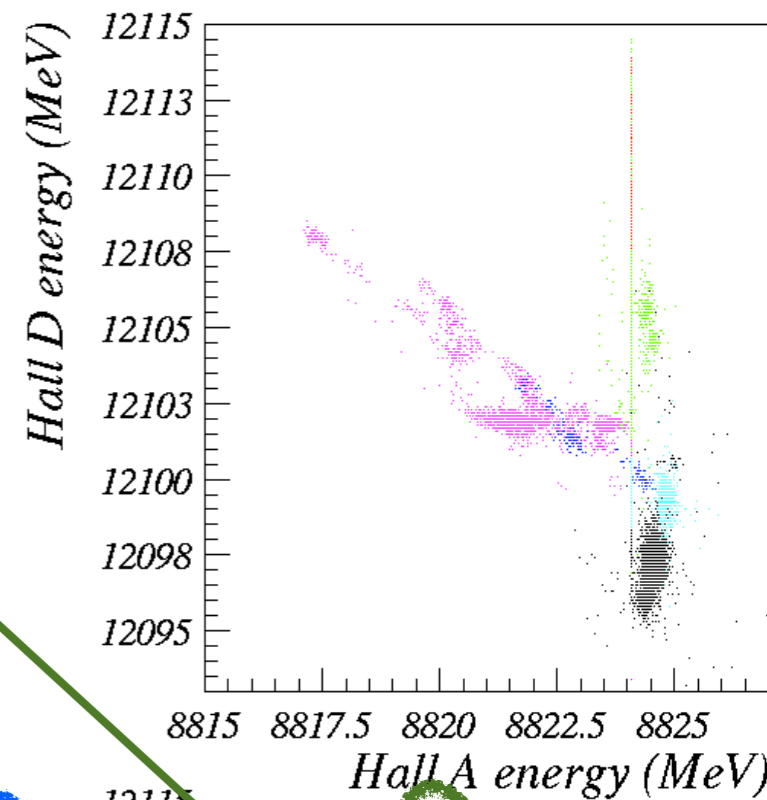
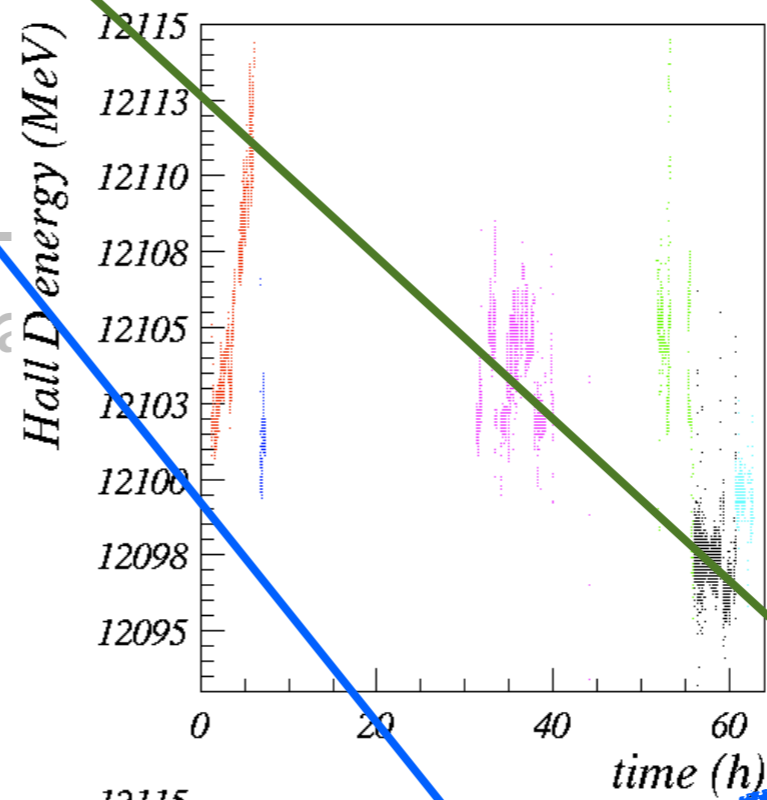
Real drifts (typically a few MeV, at worst 10

- Correlate with **x-position** (and not y) of the beam after tagger magnet

(AD00c BPM in the beam dump).

- Correlate with dispersive Hall D with non-dispersive BPM 5C08.

- Correlate with ARC energies: possibly Hall A energy change



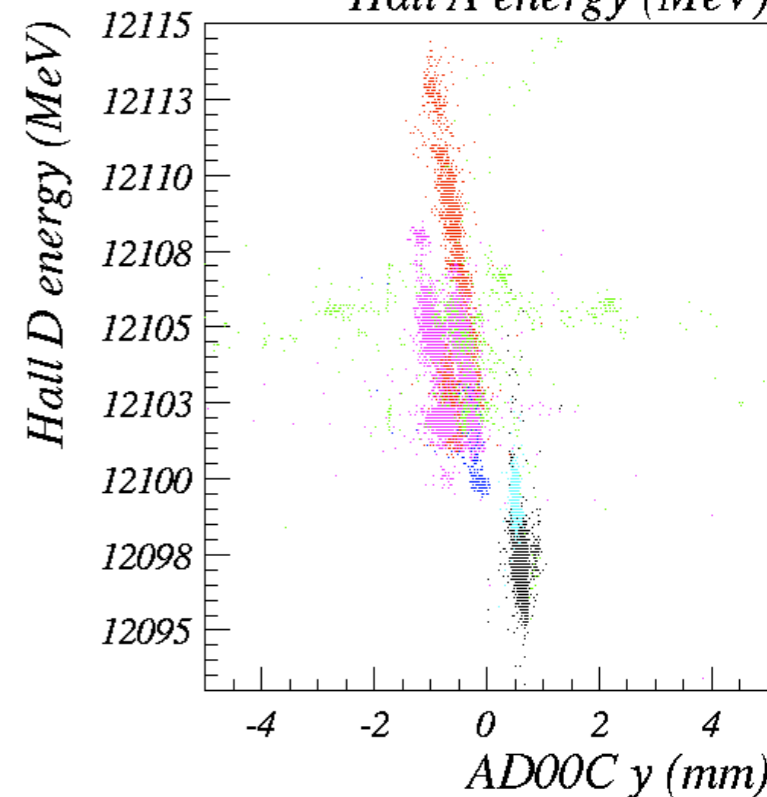
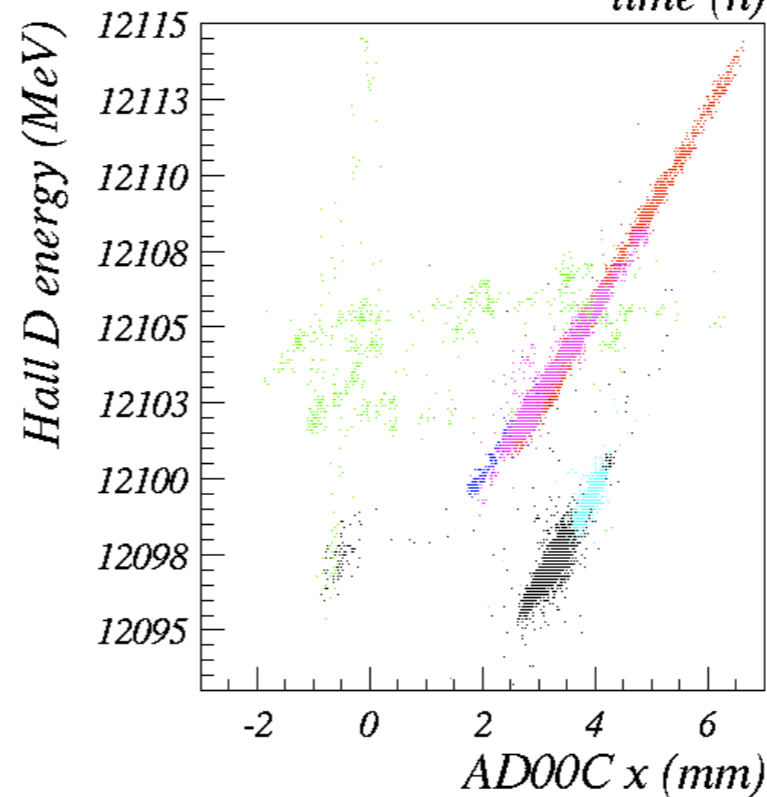
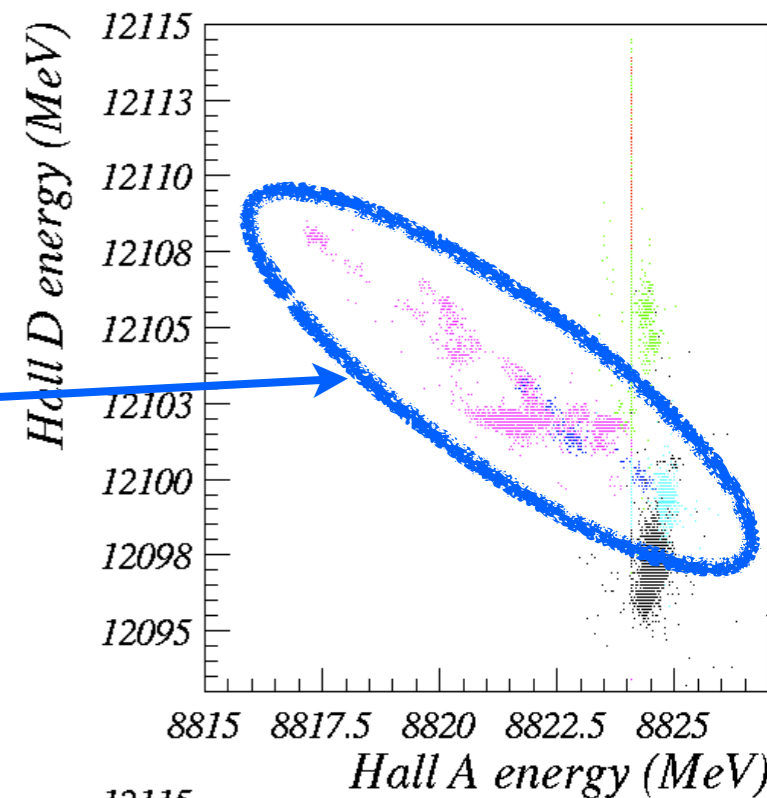
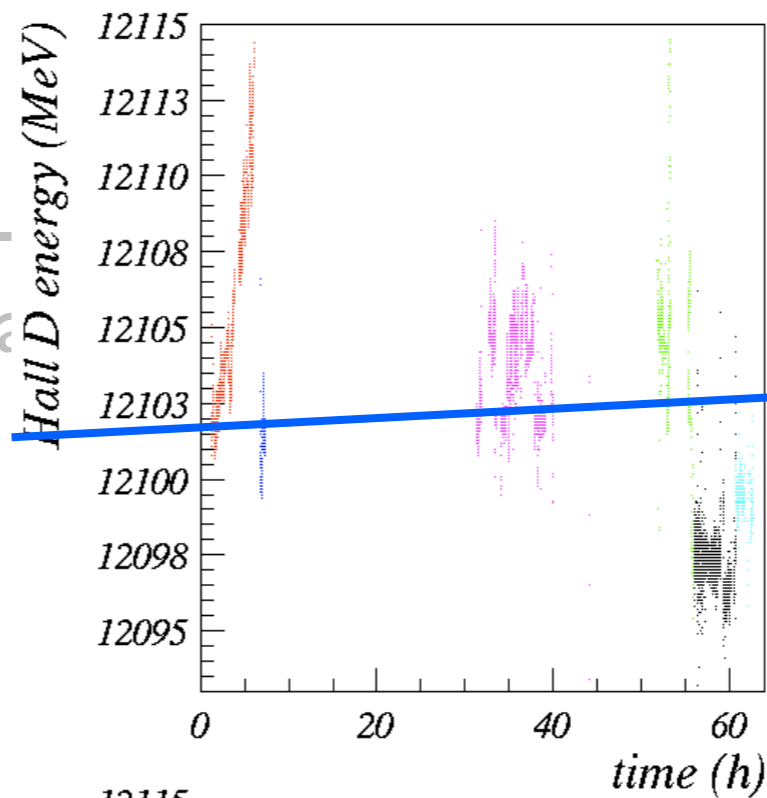
Ex. data from Feb. 29th - March 03

Real energy variations

Energy is measured from the beam

Real drifts (typically a few MeV, at worst 10

- Correlate with x-position (and not y) of the beam after tagger magnet (AD00c BPM in the beam dump).
- Correlate with dispersive Hall with non-dispersive BPM 5C08.
- **Correlate with ARC energies** ; possibly **Hall A energy** change

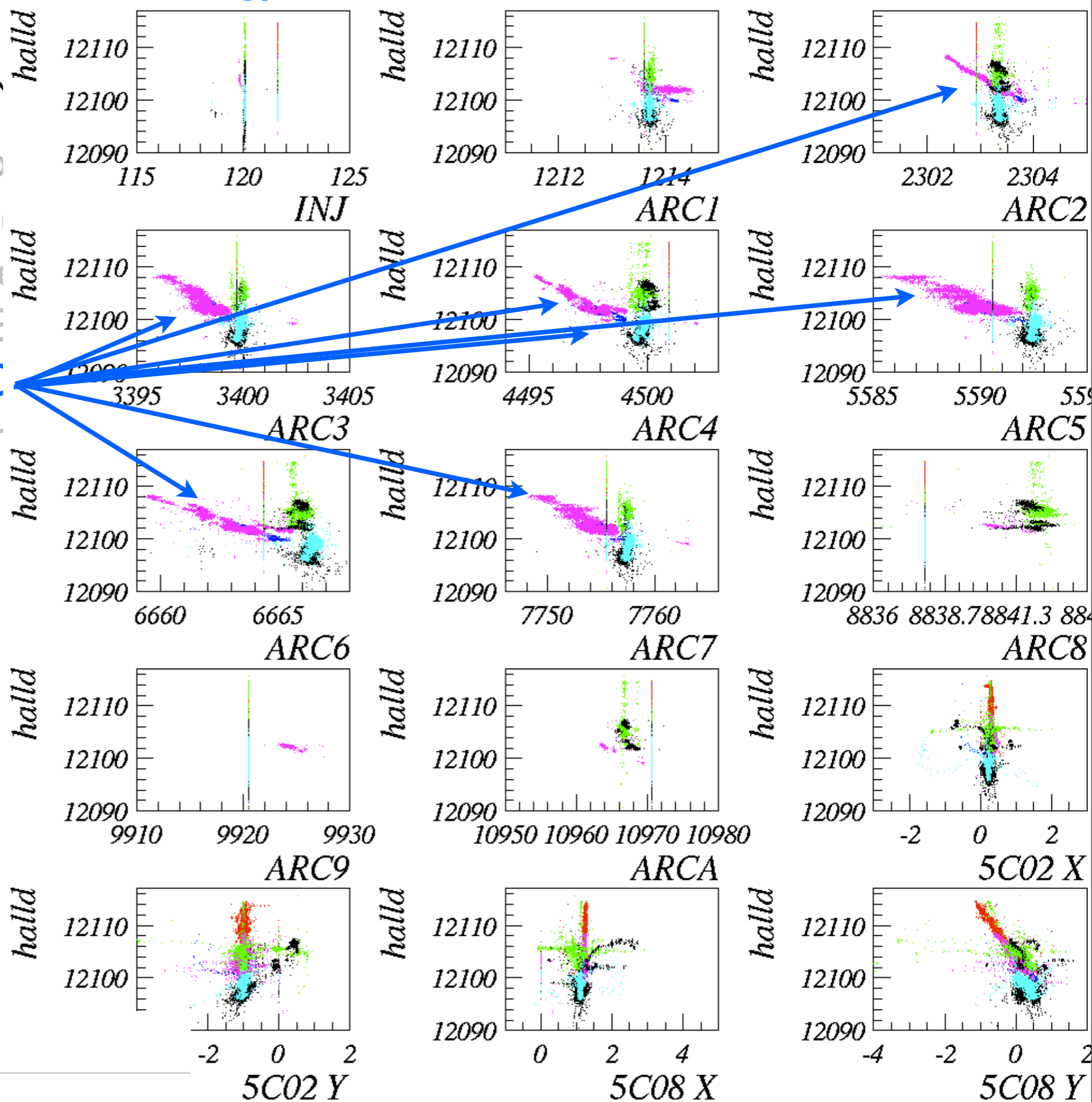


Ex. data from Feb. 29th - March 03

Real energy variations

Energy is measured from
Real drifts (typically a few μ eV)

- Correlate with x-positions (AD00c BPM in the beam drift chamber)
- Correlate with dispersion with non-dispersive elements
- **Correlate with ARC** (possibly Hall A energy)

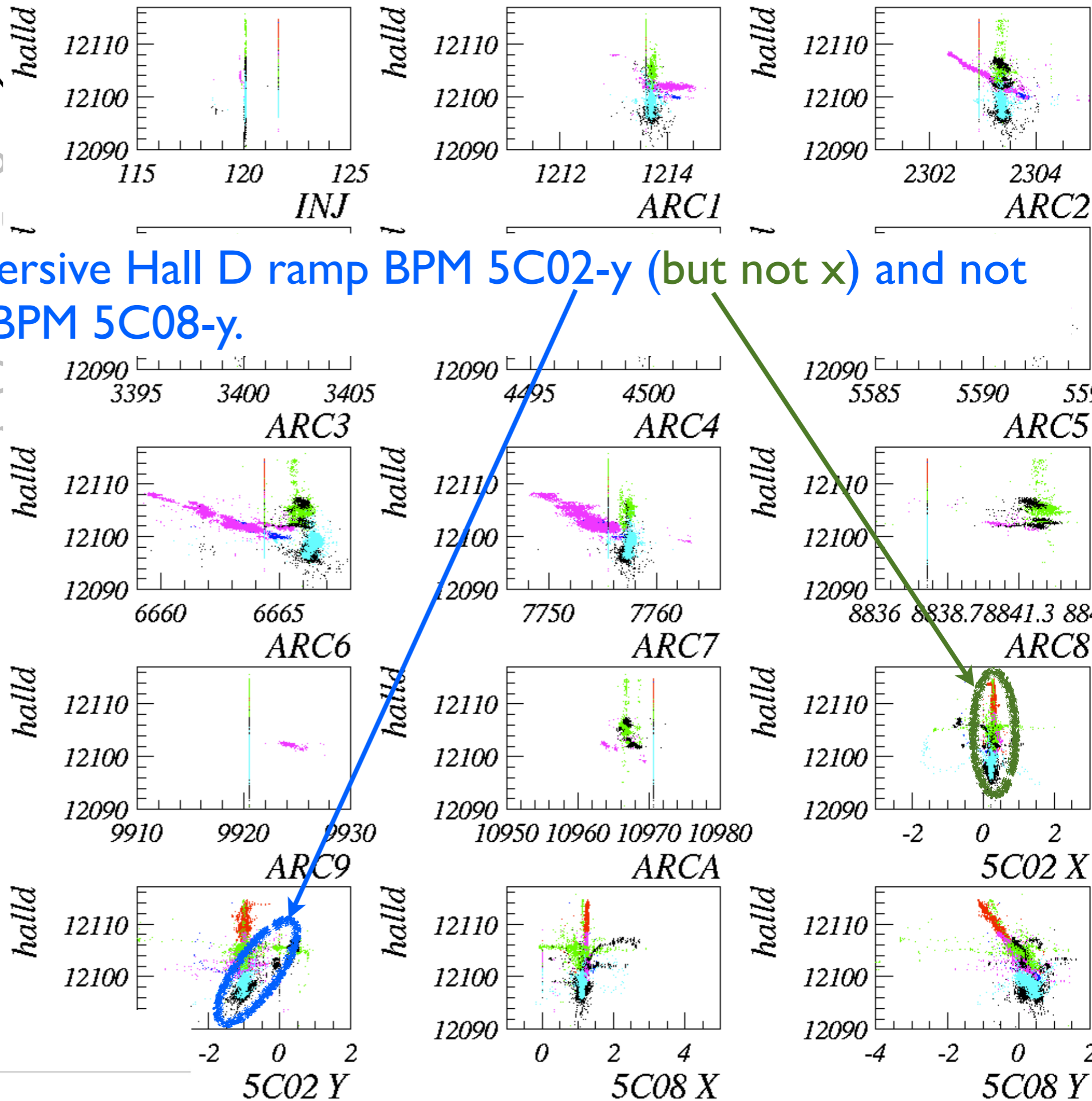


Ex. data from Feb. 29th - March 03

Real energy variations

Energy is measured from **Real drifts** (typically a few μ eV)

- Correlate with x-position (AD00c BPM in the beam drift chamber)
- Correlate with dispersive Hall D ramp BPM 5C02-y (but not x) and not with non-dispersive BPM 5C08-y.
- Correlate with ARC possibly Hall A energy



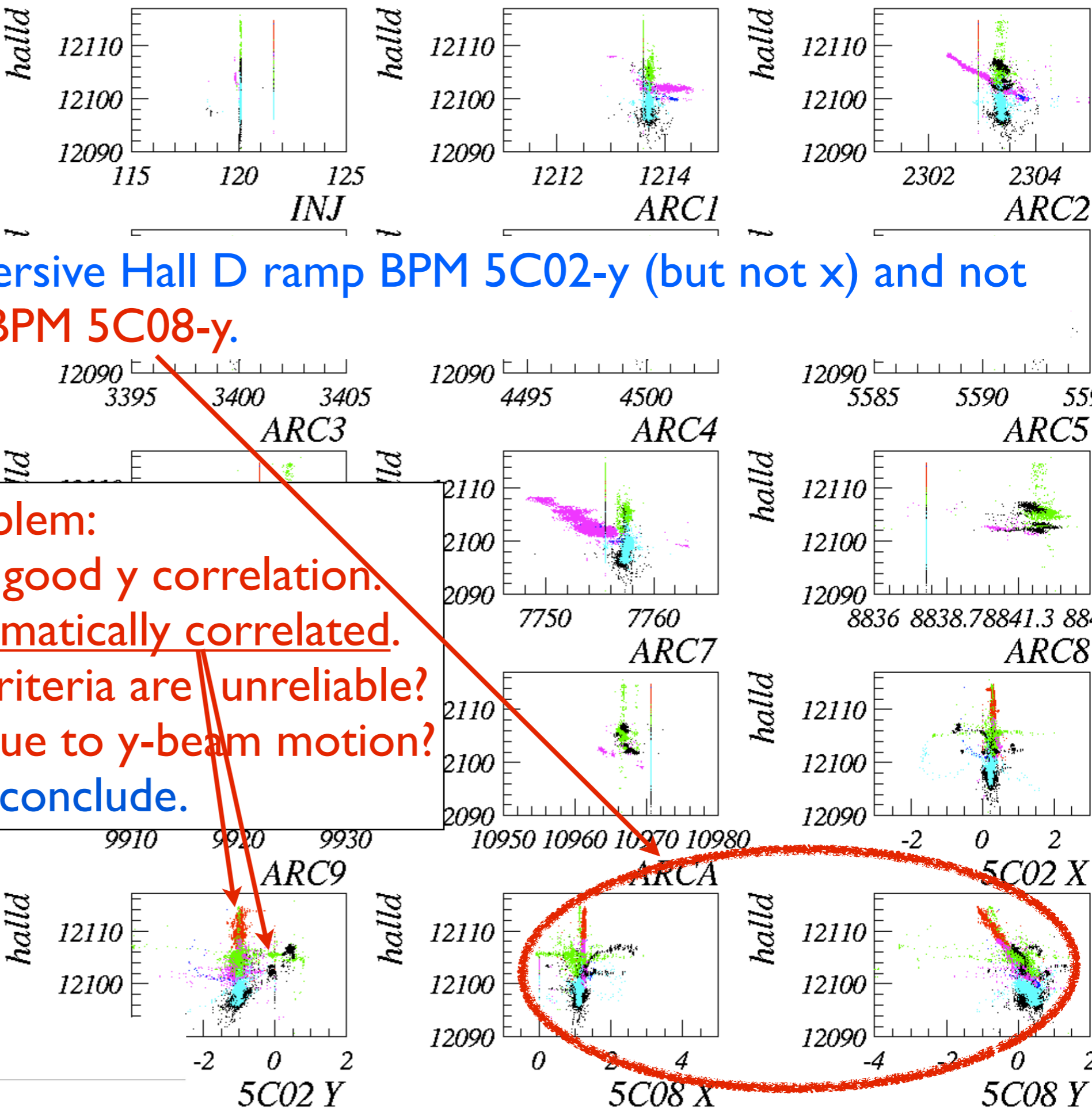
Ex. data from Feb. 29th - March 03

Real energy variations

Energy is measured from

Real drifts (typically a few μ eV)

- Correlate with x-position (AD00c BPM in the beam drift chamber)
- Correlate with dispersive Hall D ramp BPM 5C02-y (but not x) and not with non-dispersive BPM 5C08-y.
- Correlate with ARC BPMs (possibly Hall A energy)



Problem:

5C08 always has a good y correlation.

5C02-y is not systematically correlated.

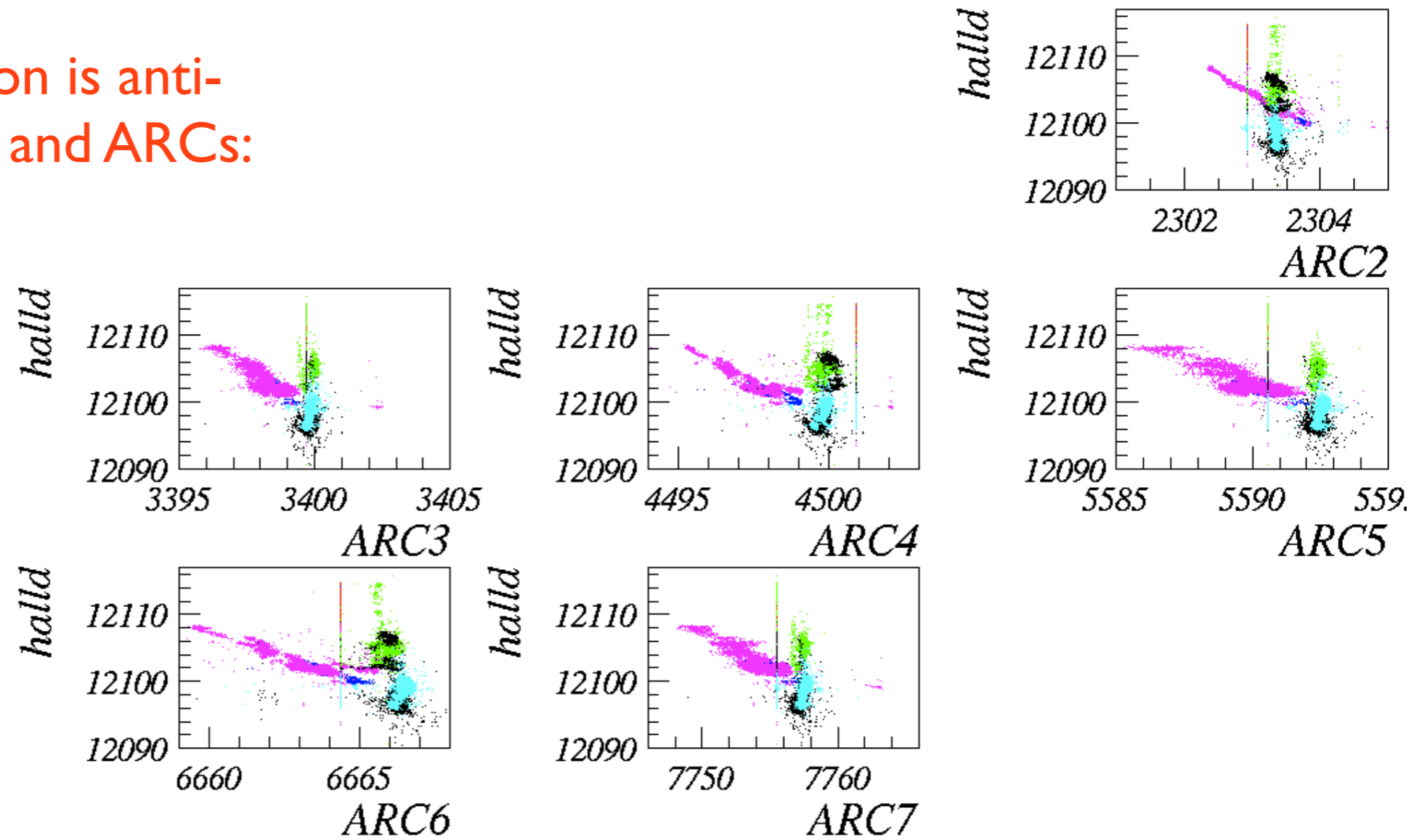
Misunderstanding? Criteria are unreliable?
energy drift artifact due to y-beam motion?

Hard to conclude.

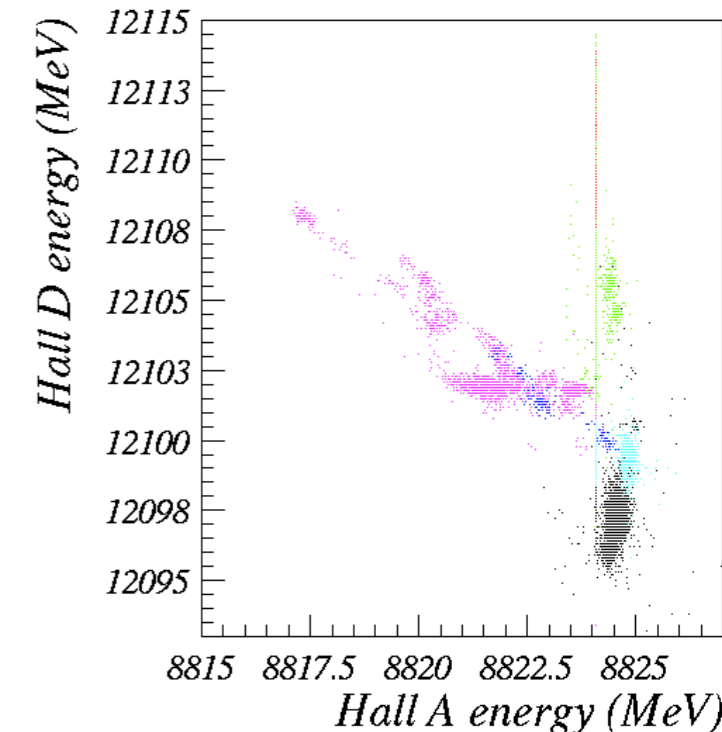
Ex. data from Feb. 29th - March 03

Anti-correlation with Hall A energy and ARCs

Hall D energy variation is anti-correlated with Hall A and ARCs:

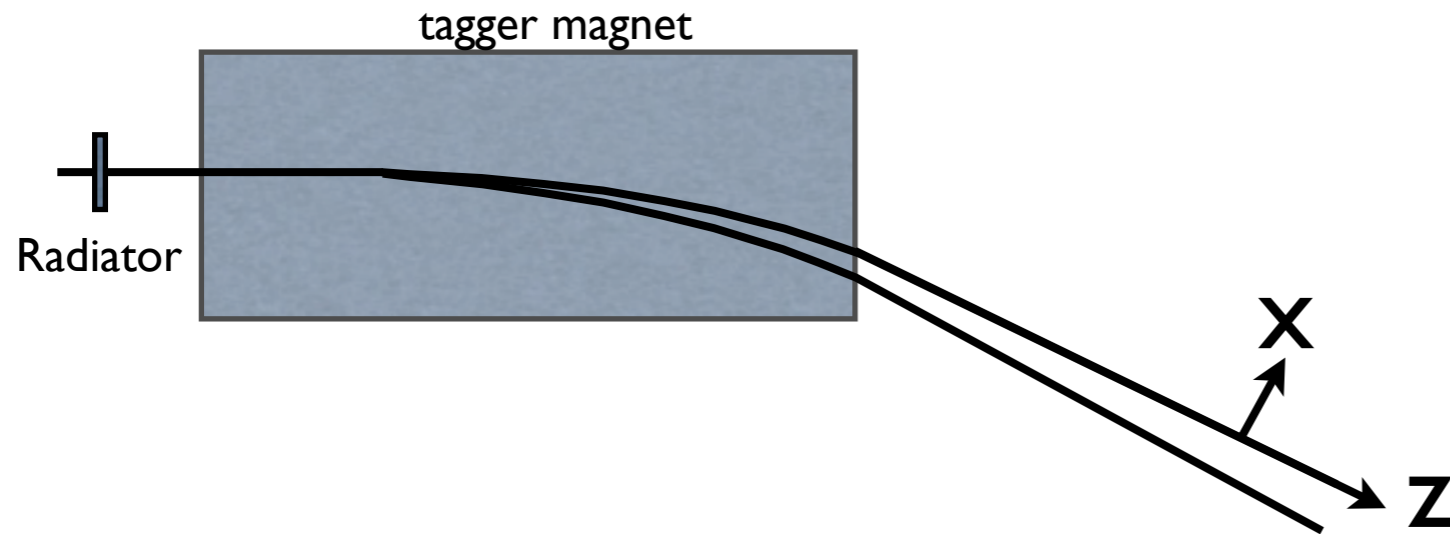


Expect a correlation. Wrong sign for Hall D energy variation?

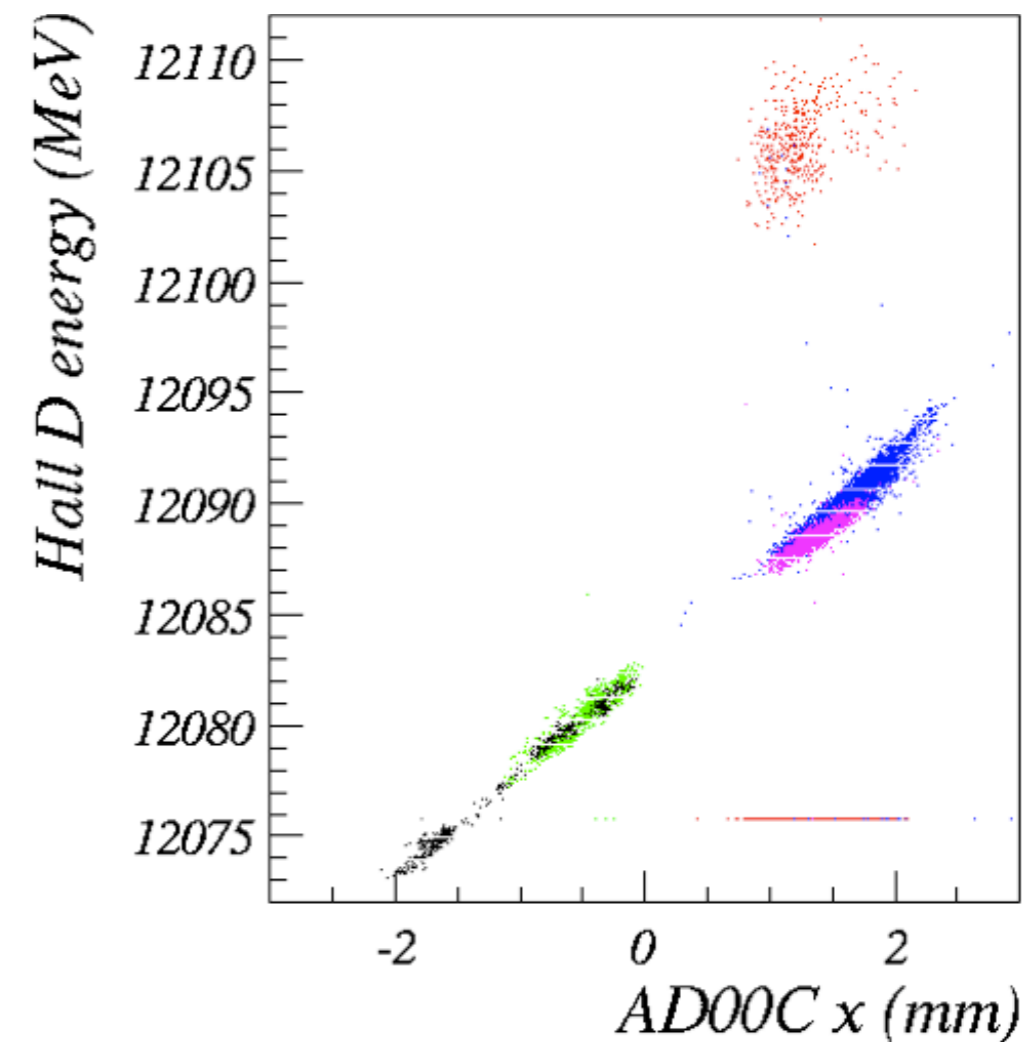


Sign verification (I)

Using tagger magnet as analyzer:



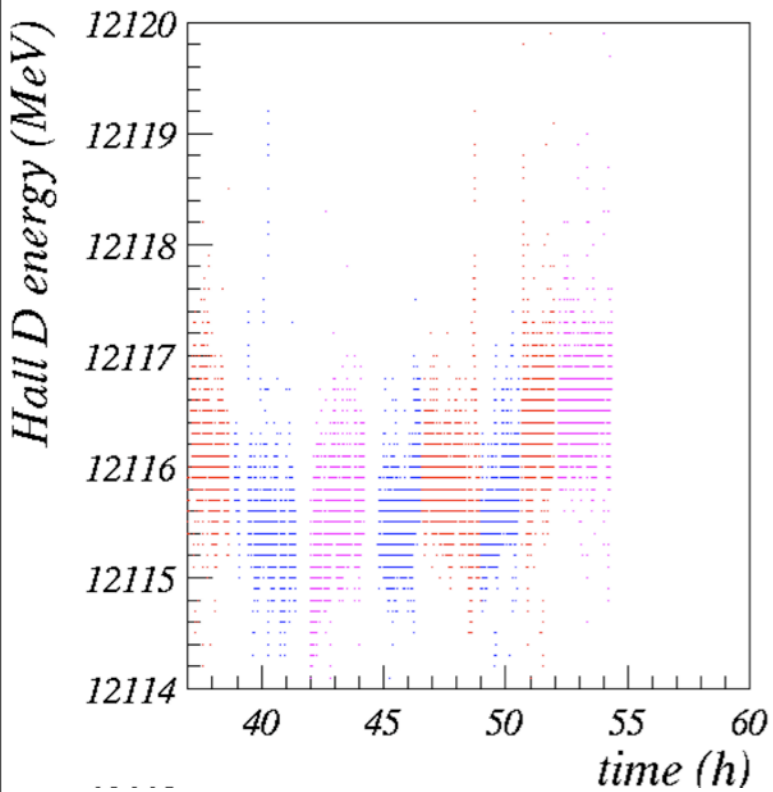
⇒ Expect larger energy at larger x,
as we see.



Sign verification (2)

Variation of beam position at tagger dump with radiator thickness:

Data from Apr. 24th - 25th



— Al. (RL=3.4 10⁻⁴)

— 50 μm diamond,
perp (RL=3.4 10⁻⁴)

— 50 μm diamond,
perp (RL=2.7 10⁻⁴)

Sign verification (2)

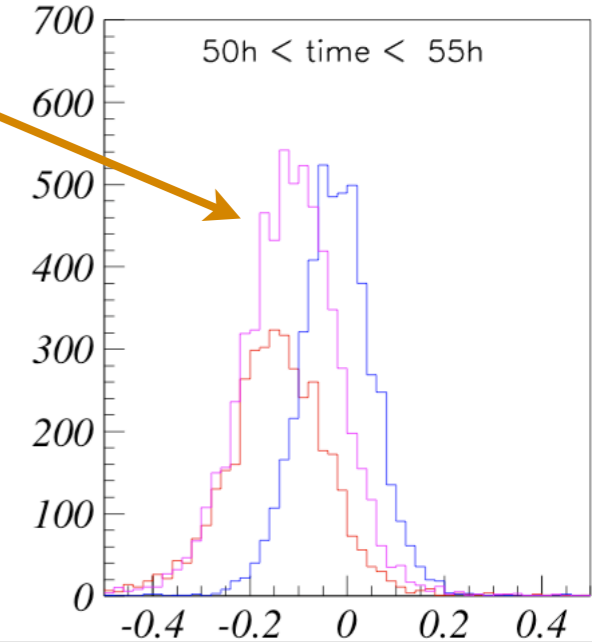
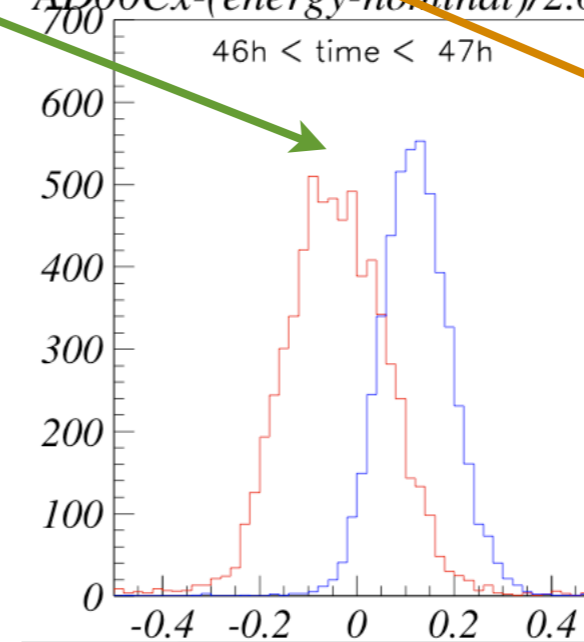
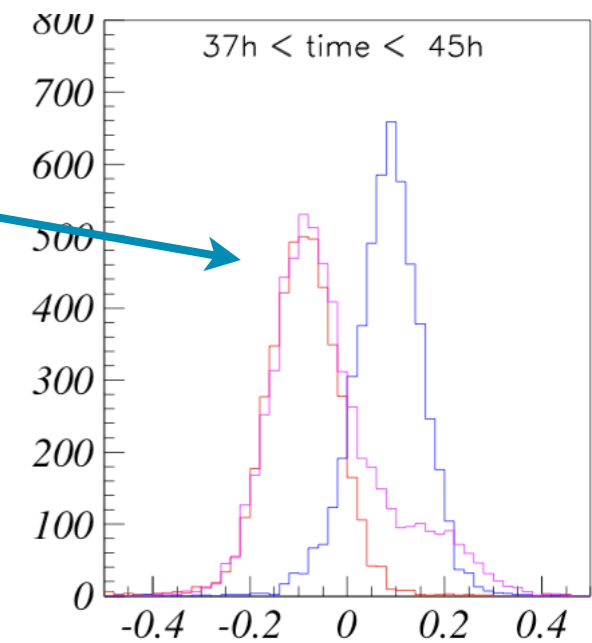
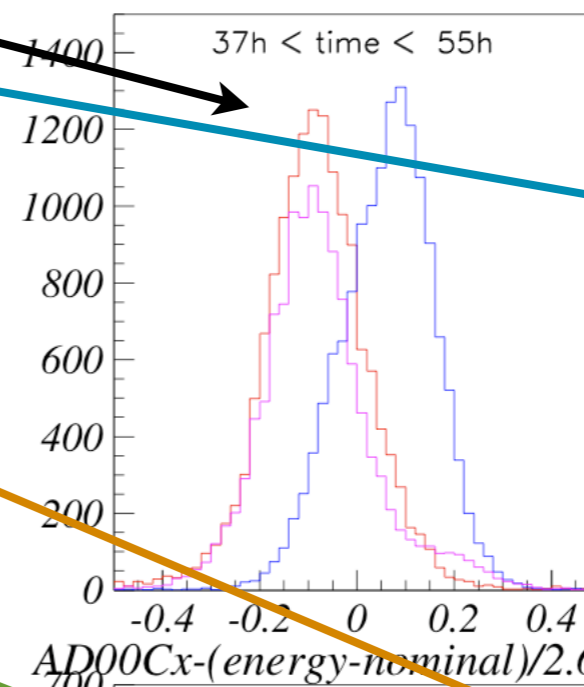
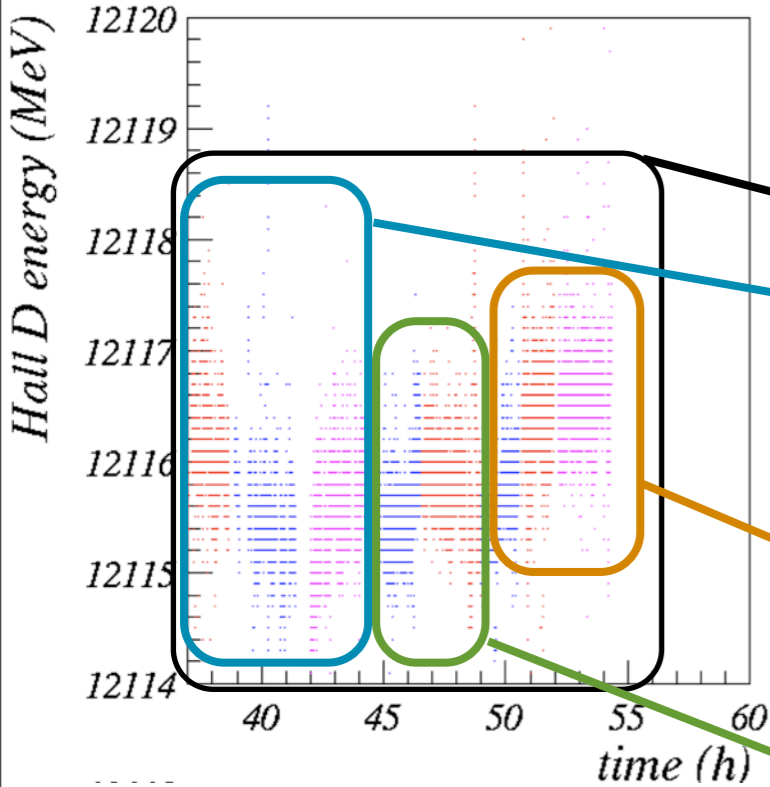
Variation of beam position at tagger dump with radiator thickness:

Data from Apr. 24th - 25th

— Al. (RL=3.4 10^{-4})

— 50 μm diamond, perp (RL=2.7 10^{-4})

— 50 μm diamond, perp (RL=3.4 10^{-4})



- Blue data (higher energy) shifted each time toward positive x.
- Red and purple overlap.

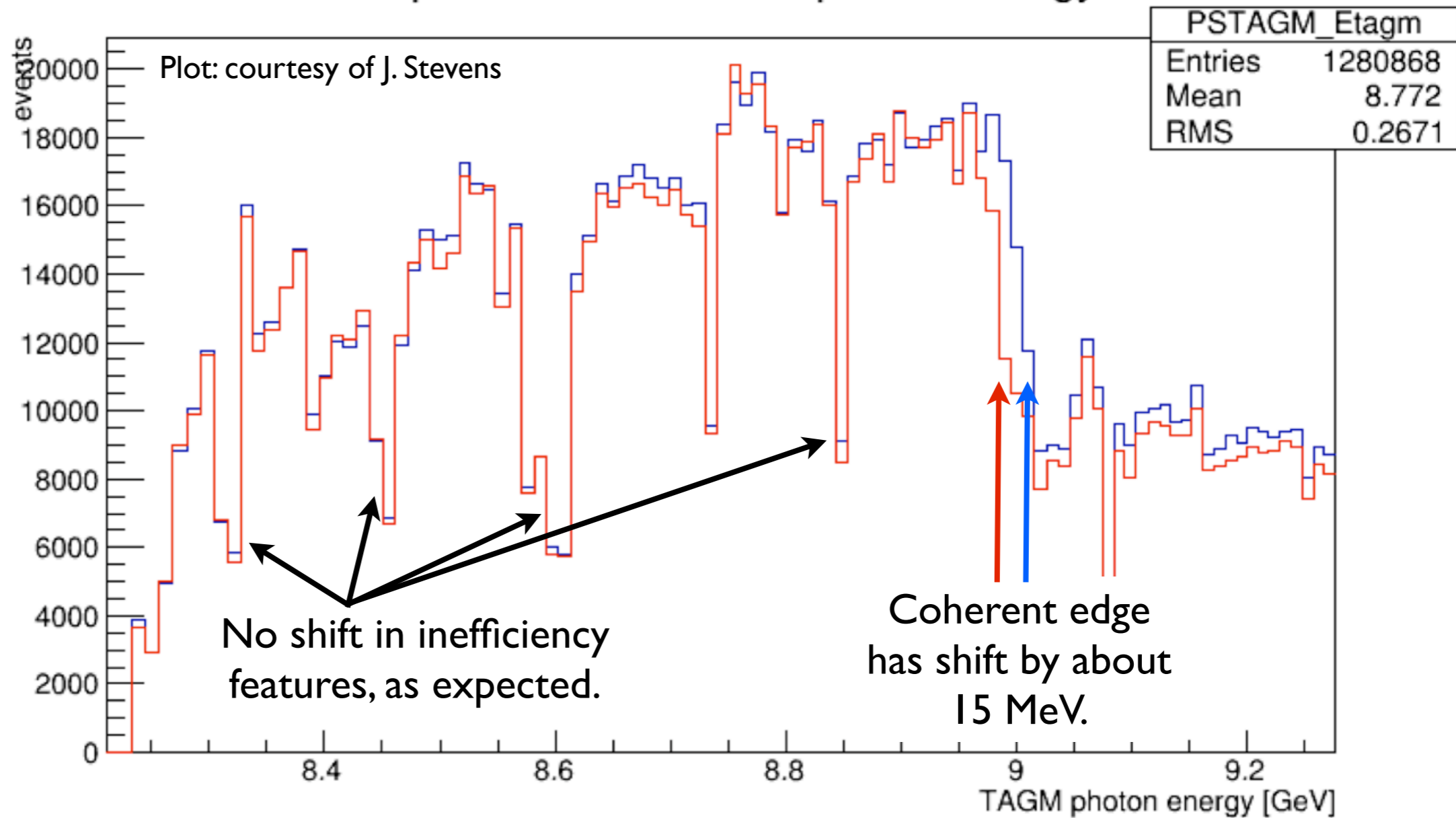
Sign verification (3)

Using tagger counters:

Blue: Run 10857, 03/08/2016 1:45am, with HALLD:p reading about 12091 MeV.

Red: Run 10867, 03/08/2016 8:20am, with HALLD:p reading about 12074 MeV.

PS pair - TAGM: TAGM photon energy



Sign verification

Energy fluctuations in Hall D have the right sign.

What is the origin of the anti-correlations?

Summary

- Hall D electron beam energy varied over a $\sim 1\%$ range during Spring 2016 run.
- Some variations are genuine, some are artifacts of measurement method.
- Can usually distinguish between both, but sometimes the nature of the variation is ambiguous.
- Non-dispersive BPM in Hall D ramp sometimes correlates with real energy fluctuation
- Origin of the artificial drifts is unclear.
- Hall D energy anti-correlates with Hall A and Arc energies.
- Energy lock is available, but was not turned on (as far as I know).
- Analysis note available.
 - Provides average energy (corrected for artificial shifts) in time periods of approximate energy stability.
 - Values with finer time binning (corrected for artificial shifts) also available.
 - Systematic analysis of the energy behavior during Spring 16 run.