Outline

- Specifications for High Intensity Running
  - Motivation, goals
- L3 trigger review
  - Charge
  - Extrapolated rates from Spring 2016 data
    - Total data rate
    - Data rate of individual crates
  - Actions to reduce event size
    - Word mapping (what takes space in EVIO file)
    - Time cuts, thresholds, TAGH
    - Estimate of rates with reduced event size
  - Review recommendations
- Level - 3 implementation
  - Data flow
  - BDT
- Outlook

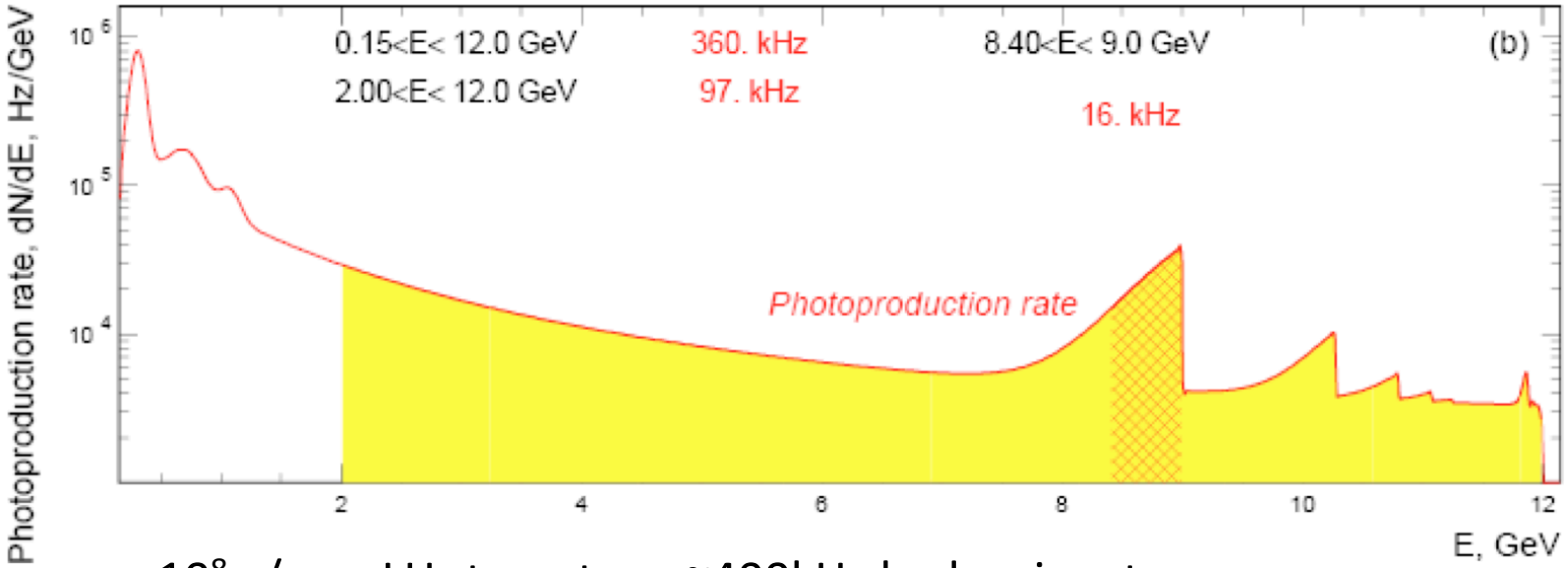
High Intensity Running in Hall-D

David Lawrence JLab

Nov. 10, 2016

From PR12-13-003 (GlueX strangeness proposal)

… we propose a gradual increase in the photon flux towards the GlueX design of 10^8 γ/s in the peak of the coherent bremsstrahlung spectrum (8.4 GeV < Eγ < 9.0 GeV). Yield estimates, assuming an average flux of 5×10^7 γ/s, are presented.

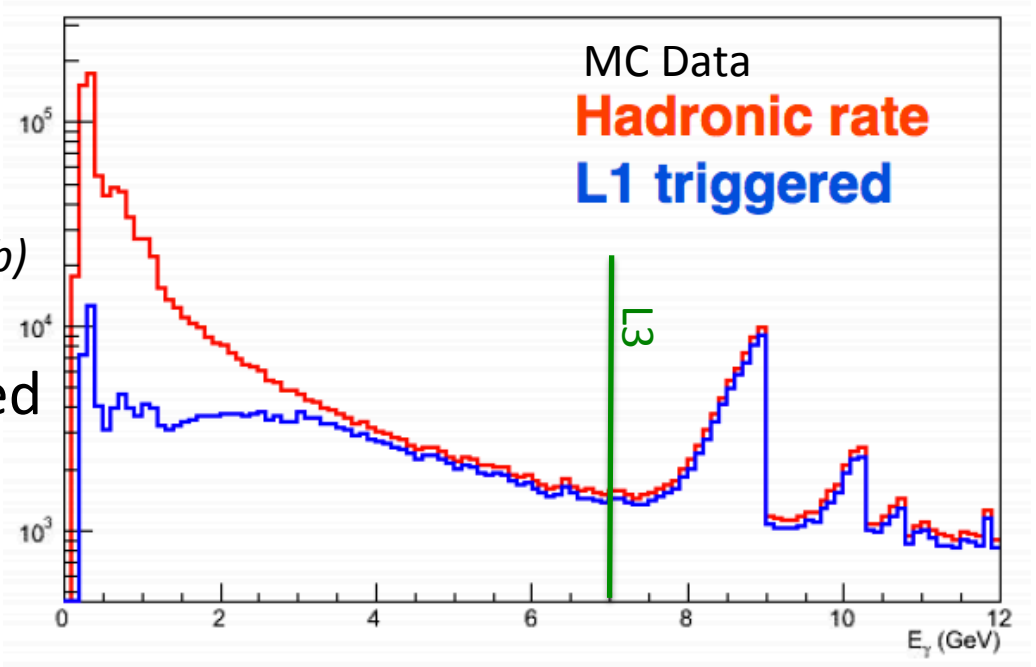


- 10^8 γ/s on LH_2 target -> ~400kHz hadronic rate
- L1 trigger goal is to cut away ~50% leaving 200kHz
- L3 trigger goal is to reduce by ~90% leaving 20kHz ***actual: ~75%***
- Early simulation suggested ~15kB/event ***actual: 16kB + 0.02kB/nA****
  - 15kB/event @ 200 kHz = 3000 MB/s (front end)
  - L3 reduction by factor of 10 = 300MB/s to RAID disk

*50μm diamond, 5mm collimator

L3 Algorithm Strategy

- Use Multivariate Analysis such as BDT or ANN to classify events *(similar to LHCb)*
- Multiple levels may be used with each level requiring more expensive input variables



- Use fully reconstructed, real data to provide training samples (signal and background)
- Simultaneously pursue with simulated data

L3 Trigger mini-Review

- Quickly organized for July 22nd 2016
- Standard review procedure of critical system for experiment that will run in 2018

From: **Patrizia Rossi** rossi@jlab.org
Subject: L3 mini-review
Date: July 18, 2016 at 4:54 PM
To: David Lawrence davidl@jlab.org, Eugene Chudakov gen@jlab.org
Cc: Rolf Ent ent@jlab.org, gomez@jlab.org Gomez gomez@jlab.org, patrizia rossi rossi@jlab.org

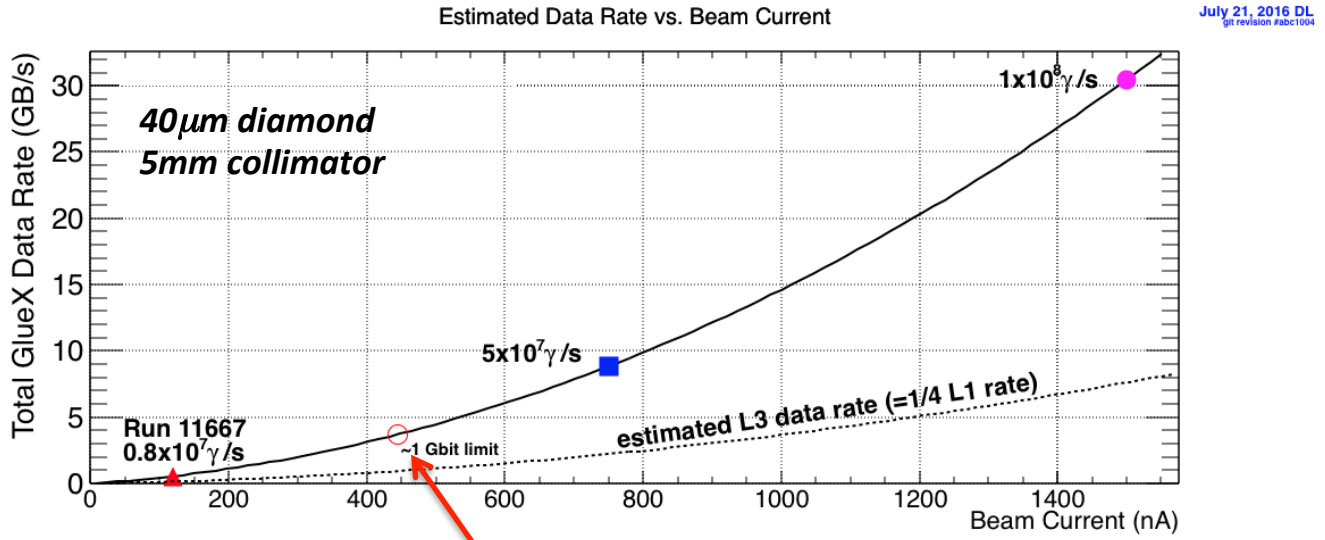
Hi Eugene, Dave,

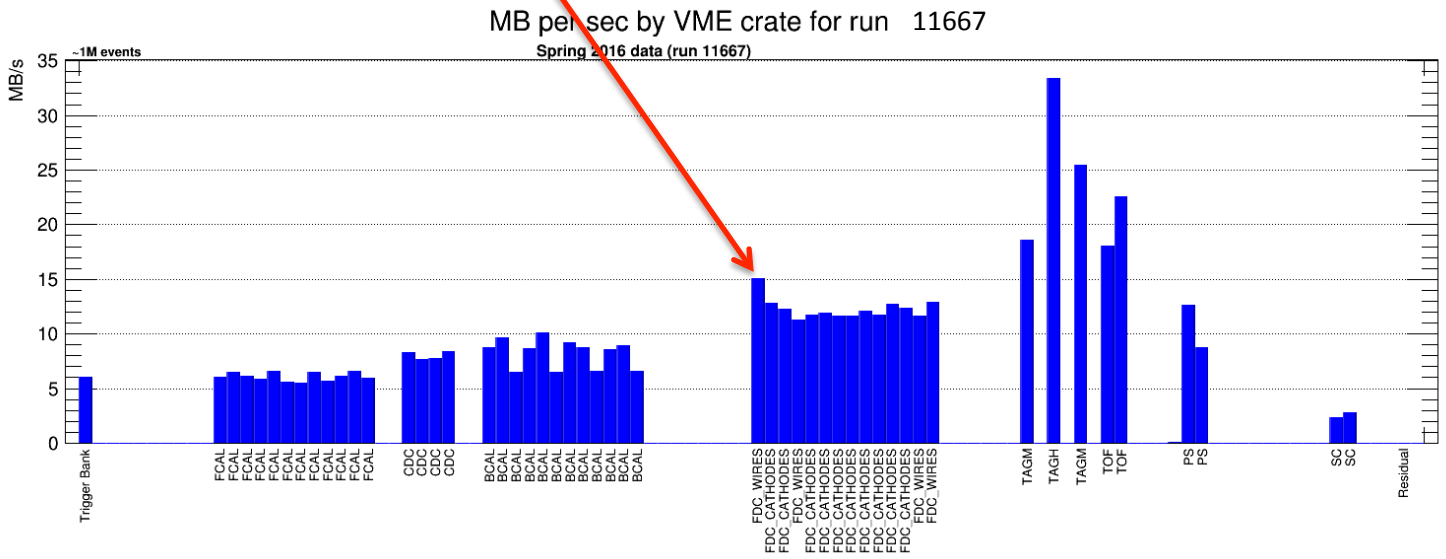
we confirm you that we will have the Hall D L3 min-review on Friday July 22.
We will start at 1pm and plan to finish by 3pm.
Amber Boehnlein and Steve Wood kindly agreed to be the subject matter experts for this review.
The charge is to assess the status of the L3 trigger and plan to completion.
Please prepare a ~1/2 hour presentation to answer this charge.
Also may you please schedule the meeting on Amber's and Steve's calendar?

Thank you

patrizia

Shown at July 22nd L3 Review

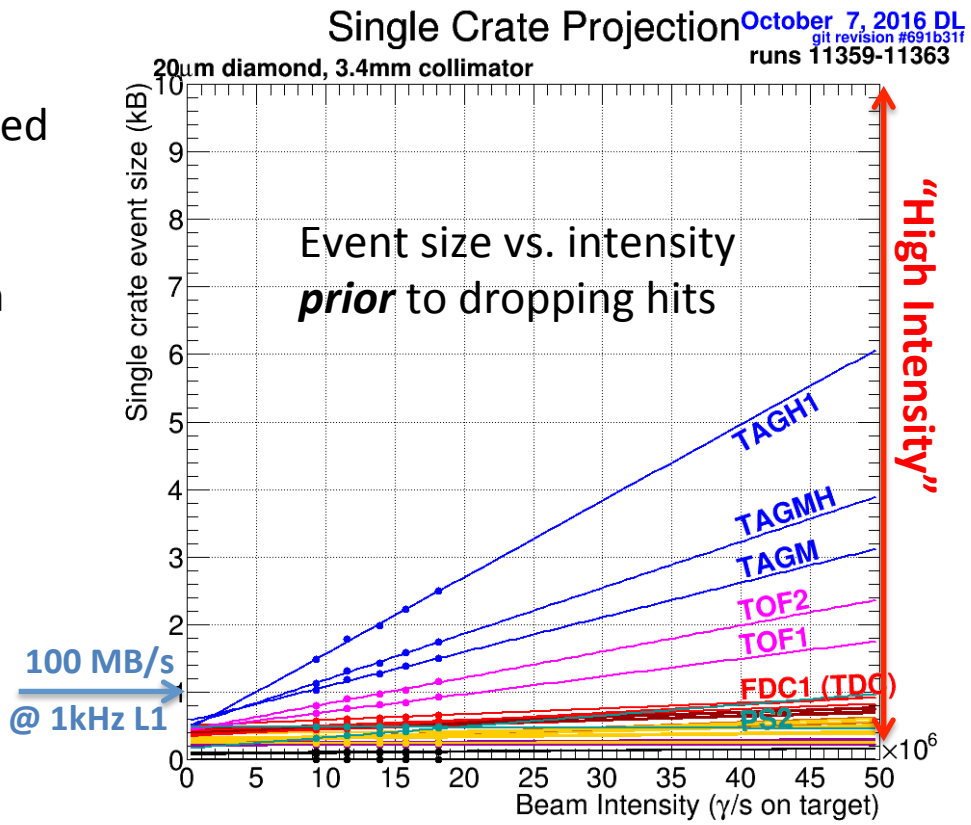




Improvements since L3 Review

- Alternate Spring 2016 data extrapolated to "High Intensity" ($5 \times 10^7 \gamma$/s)
- Better understanding of photon beam intensity
- Timing windows reduced
- Thresholds increased

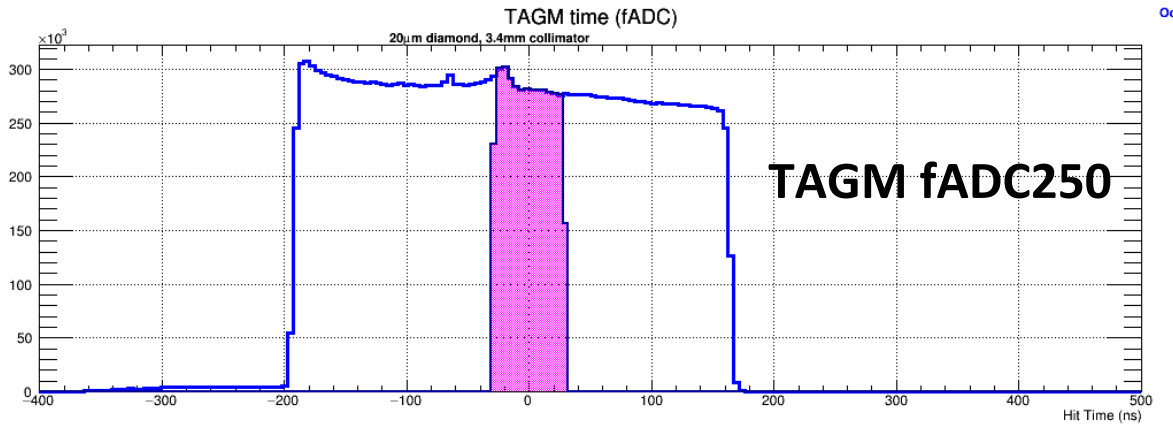
From raw data EVIO file

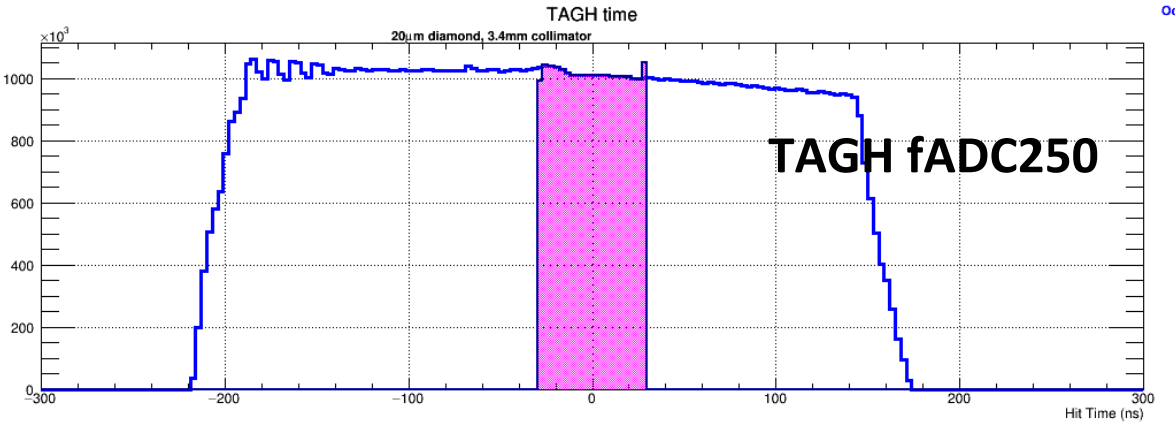


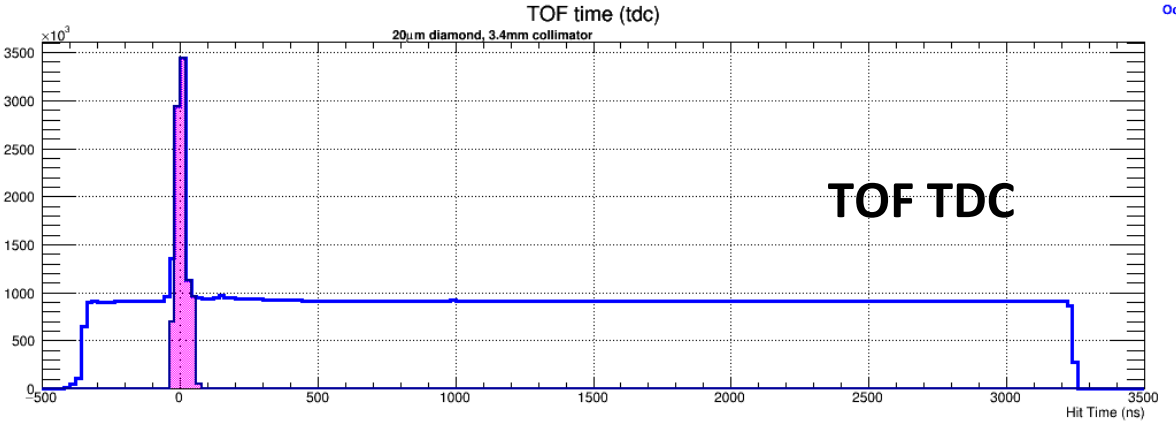
Timing cut examples

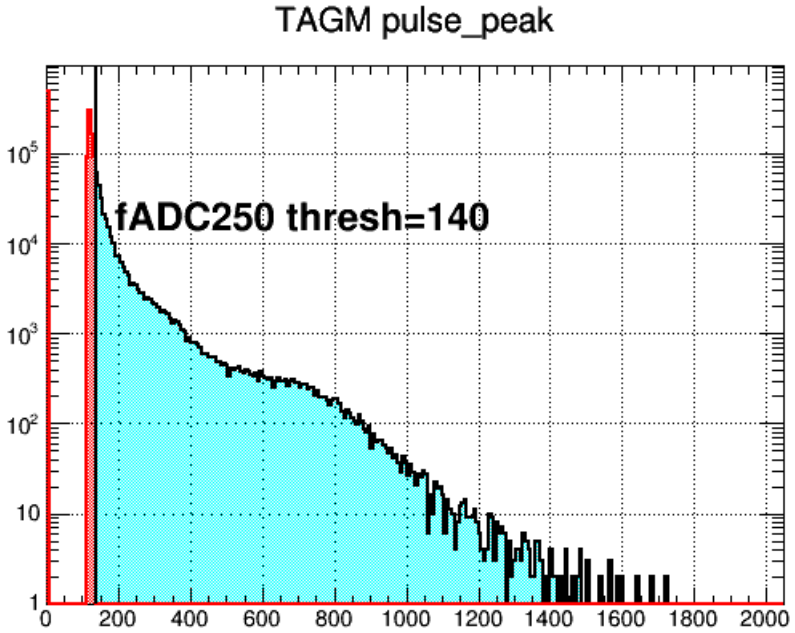
Hits outside of the shaded areas were dropped before writing out the reconstituted EVIO file

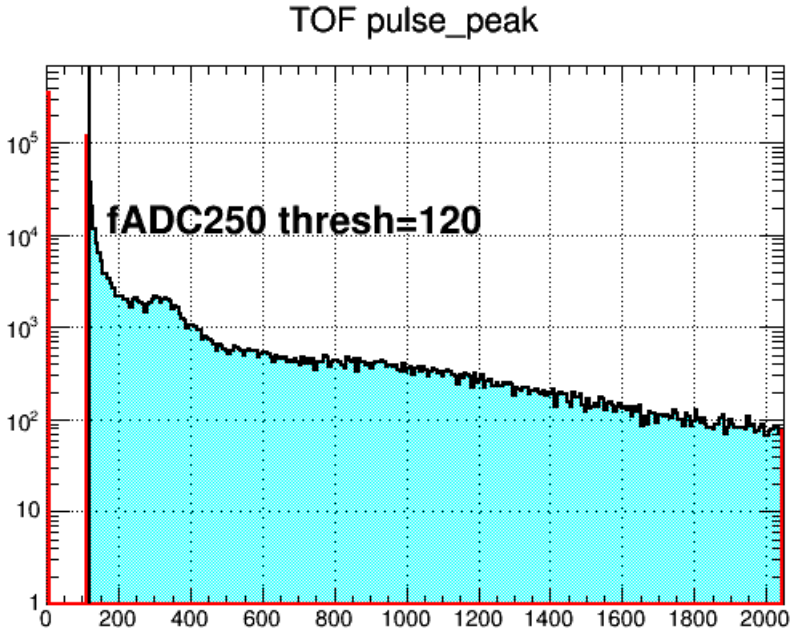
Cuts made on fully calibrated times. Cuts done in modules will be on uncalibrated times

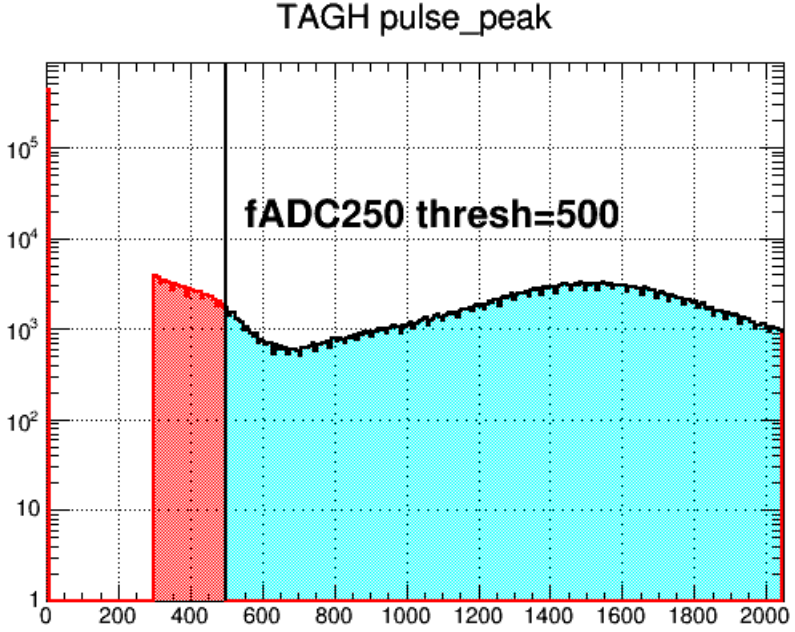


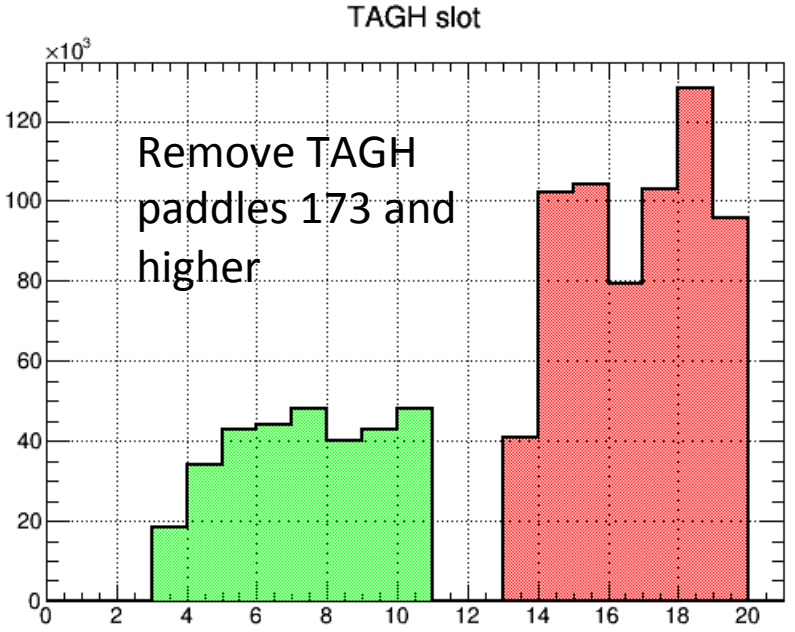




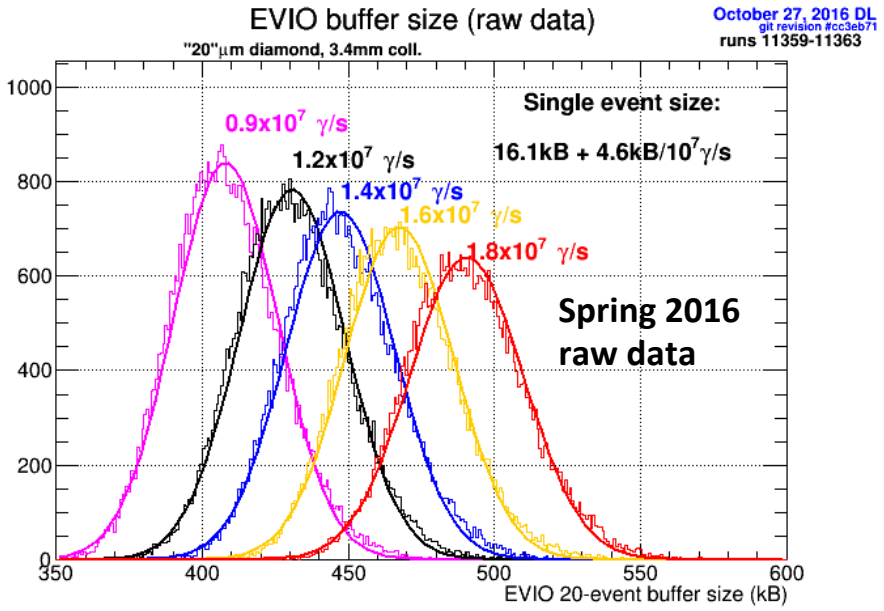

TAGM pulse_peak
fADC250 thresh=140

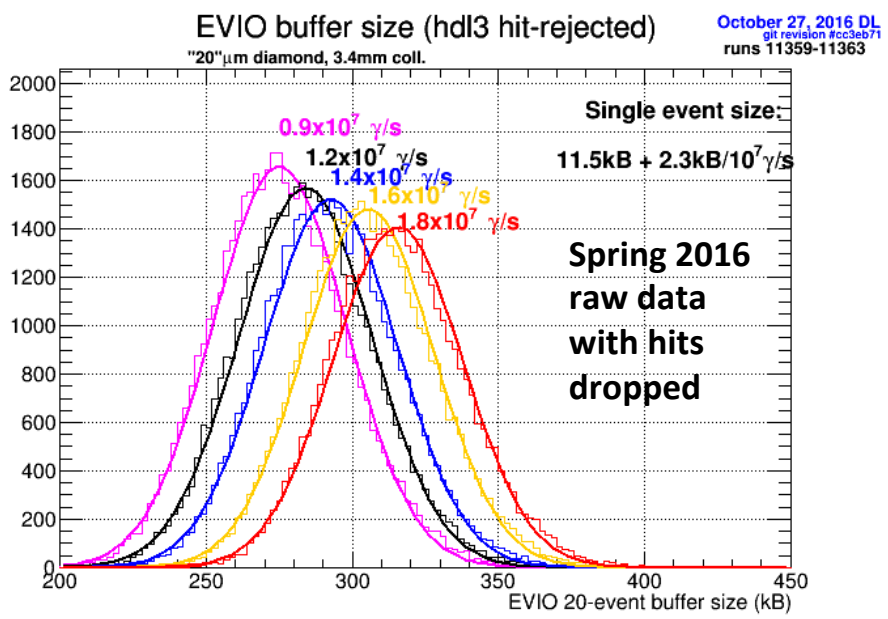

TOF pulse_peak
fADC250 thresh=120


TAGH pulse_peak
fADC250 thresh=500


TAGH slot
Remove TAGH paddles 173 and higher

Event Size vs. Beam Current





E_e- = 12.113GeV
20μm diamond
3.4mm collimator
200nA = 0.93x10^7 γ/s

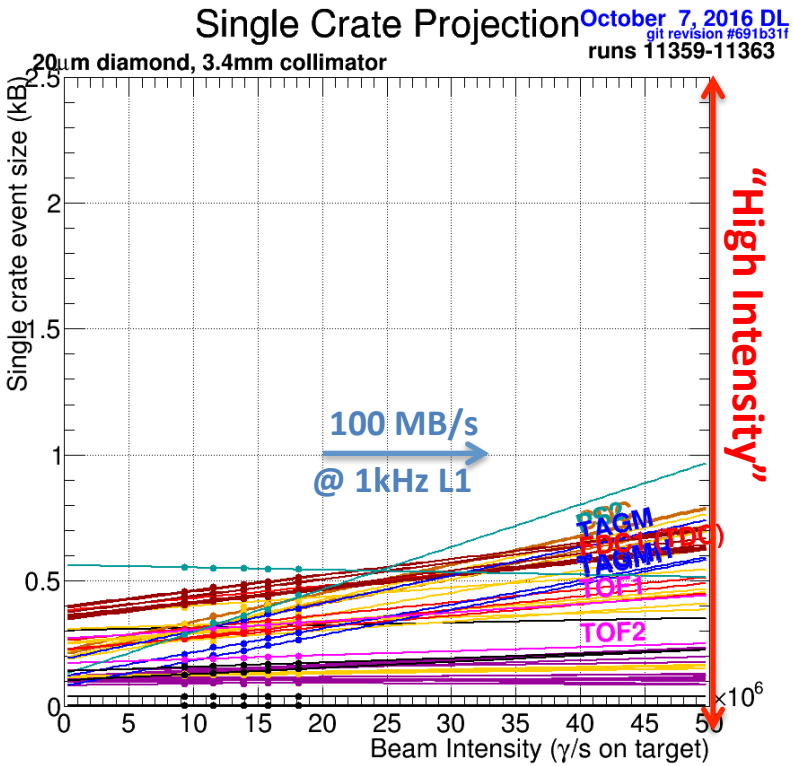
Event Size: ~14kB (low intensity)

extrapolate to $I_{beam} = 0$ → 11.5kB/event
(size of clean event with no accidentals)

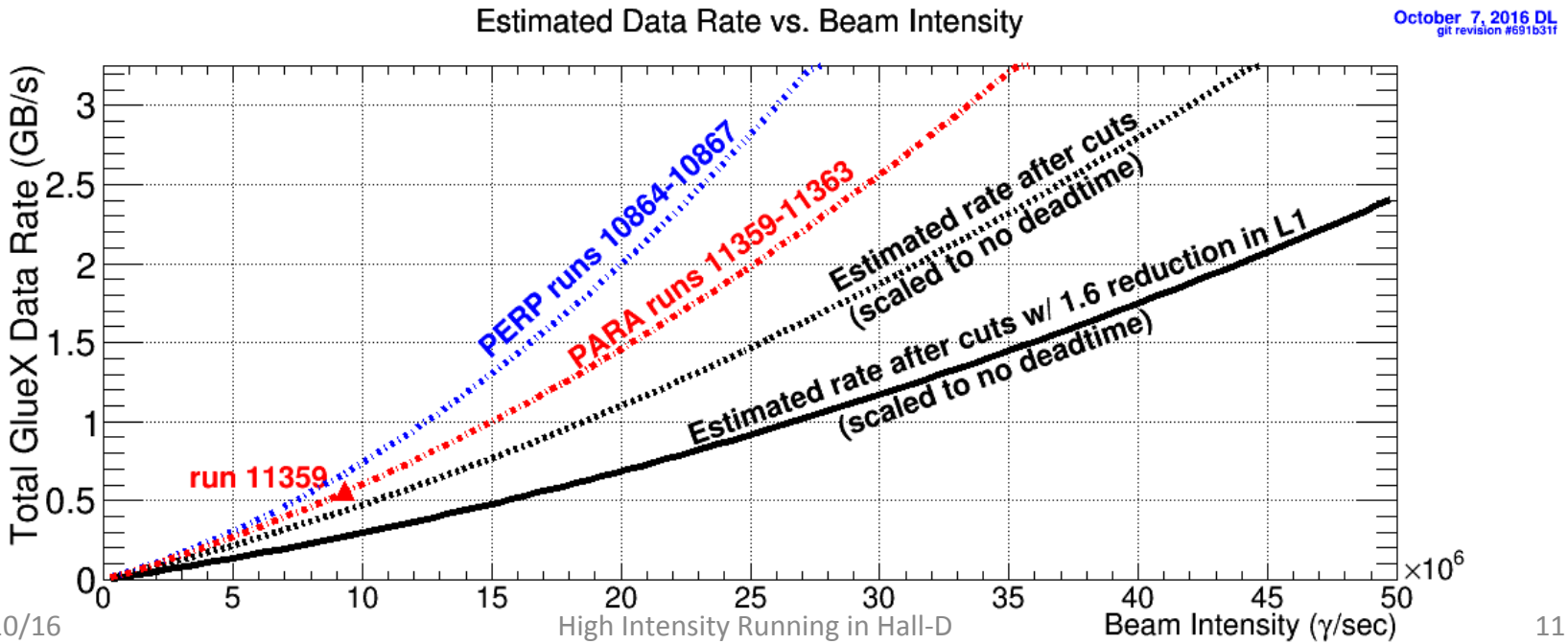
Accidental data fraction (by volume):

$$\frac{(0.01\text{kB/nA})(I_{beam}\ \text{nA})}{(0.01\text{kB/nA})(I_{beam}\ \text{nA}) + (11.7\text{kB})}$$

0.9 γ/s: 15% of data is due to accidentals
1.8 γ/s: 26% of data is due to accidentals
5.0 γ/s: 50% of data is due to accidentals



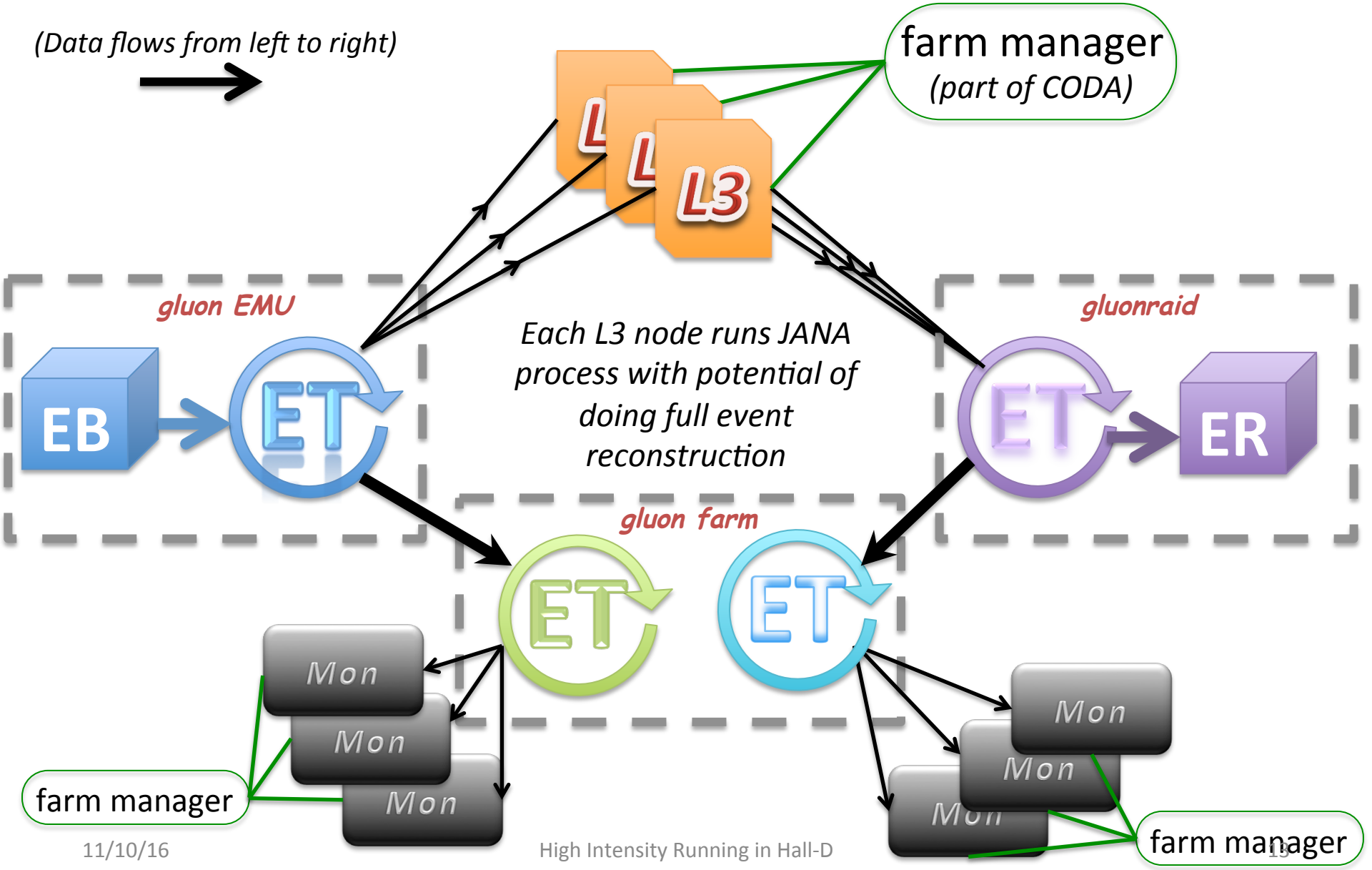
- Single crate rates can be reduced to levels below VME bandwidth limit and the 1Gbit Ethernet limit
- With no changes to L1, the extrapolated rate for high luminosity is 170kHz
- Estimated reduction in L1 rate is 1.6 in addition to what is shown below



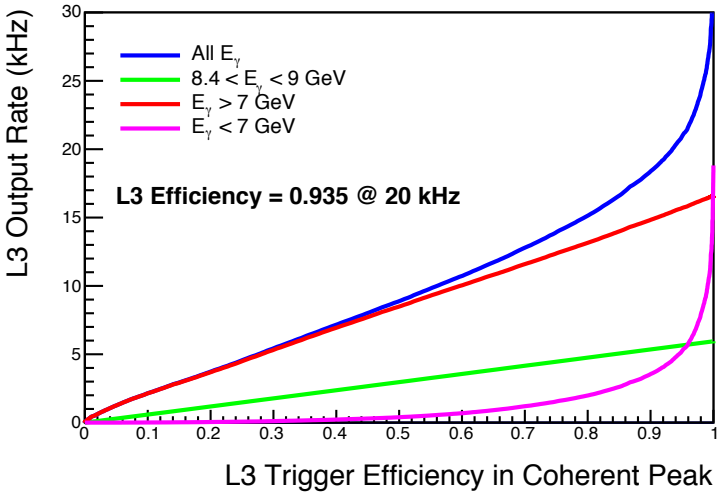
L3 Mini-review Recomendations

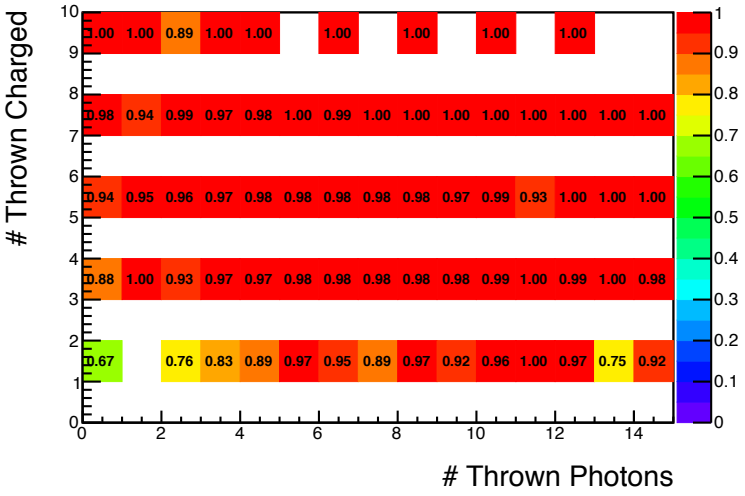
- fADC125 (performance issues)
  - **New firmware has been deployed that uses increased clock speed for VME transactions. Busy signals installed and testing underway**
- L1 trigger (optimize to reduce rate)
  - **Study by trigger expert suggests rate can be lowered by a factor of 1.6**
- Crate level readout (rate limited by 1Gbit link)
  - **Installed 10Gbit card in one crate and tested link to 8Gbyte/s. Will test with CODA during Fall run**
- System level readout (architecture and offline resources e.g. tape)
  - **Expect pre-L3 rate to be closer to 3GB/s design goal. If L3 reduction is factor of 4, then rate is only 750MB/s to disk.**
- L3 strategies (reconstruction rates with increased accidentals)
  - **High intensity test data will be obtained during Fall 2016 run (with low livetime). L3 algorithms will be benchmarked using this.**
- L3 system design (e.g. farm in counting house vs. Computer Center)
  - **Discussion deferred pending high intensity testing planned for Fall 2016**

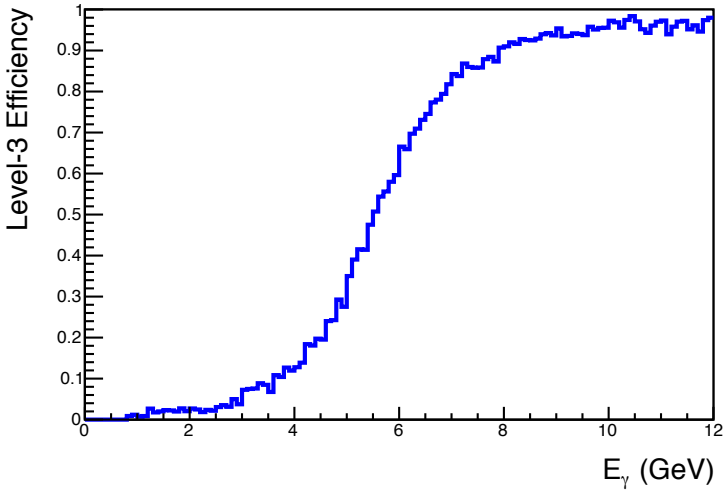
L3 and monitoring architecture



Level-3 BDT Evaluation







- Machinery resurrected for training and evaluating BDT for simulation
- Similar performance as seen in studies ~2 years ago
- Lower efficiency for low multiplicity final states

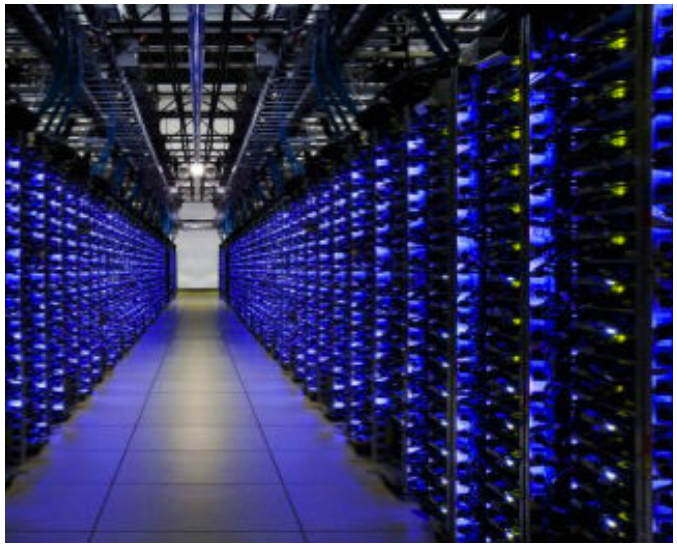
Summary and Outlook

- Spring 2016 data indicates data rates can be achieved that fit within existing hardware capabilities
- Additional high intensity testing has been incorporated into the Fall 2016 run plan
- L3 software:
  - Couples with DAQ system and offline reconstruction
  - Expect to use BDT(s)
  - Beam testing started in Spring 2016, will continue in Fall

Backup Slides

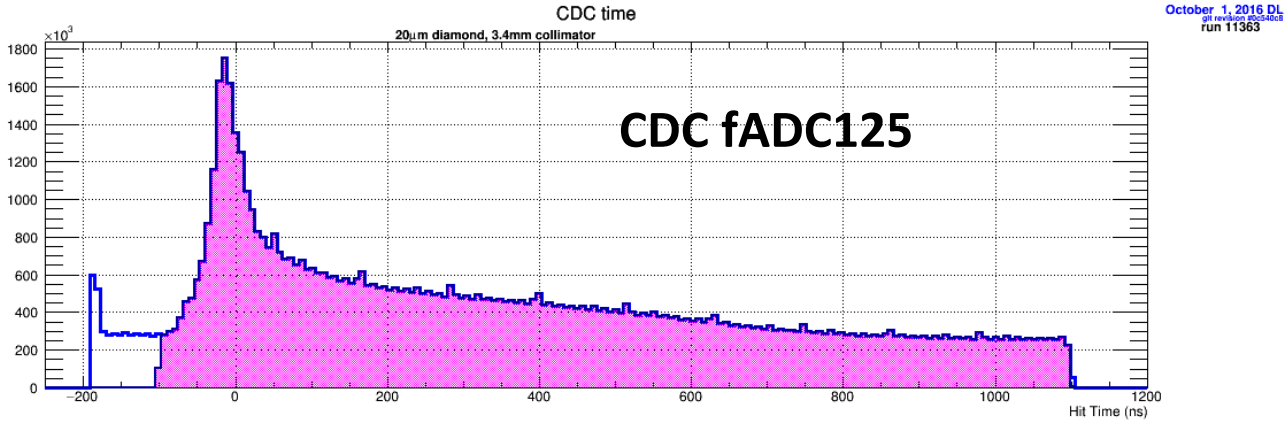
Estimated number of L3 nodes

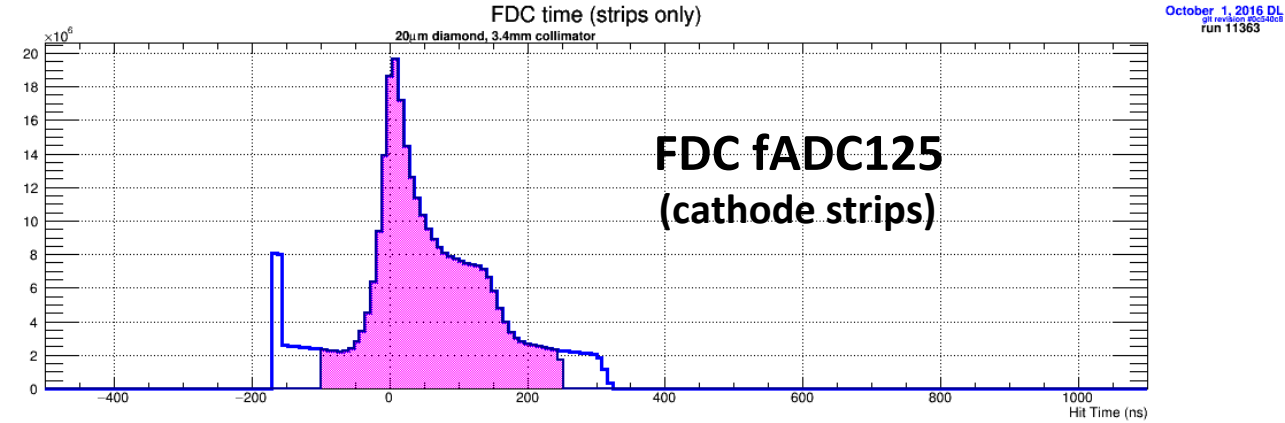
- From Spring 2016 running: ~32kHz/0.93x10^7 γ/s
- For 5x10^7 γ/s: ~170kHz
- Anticipated L1 reduction factor: 1.6
  - L1 trigger rate: ~100kHz
- 2013 Ivy Bridge nodes
  - 2.5-13kHz parsing only
  - 4kHz parsing+neutrals recon
  - 1kHz final algorithm *(conservative estimate)*
- Newer nodes more than x2 faster
  - 2kHz/node
- Total estimated number of nodes required:
  - 100kHz/4kHz = **50**

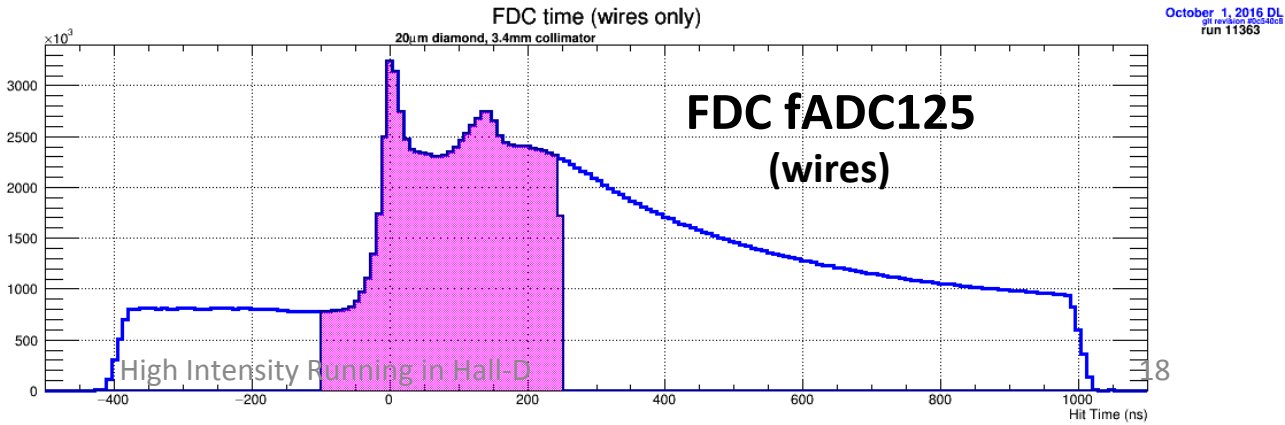


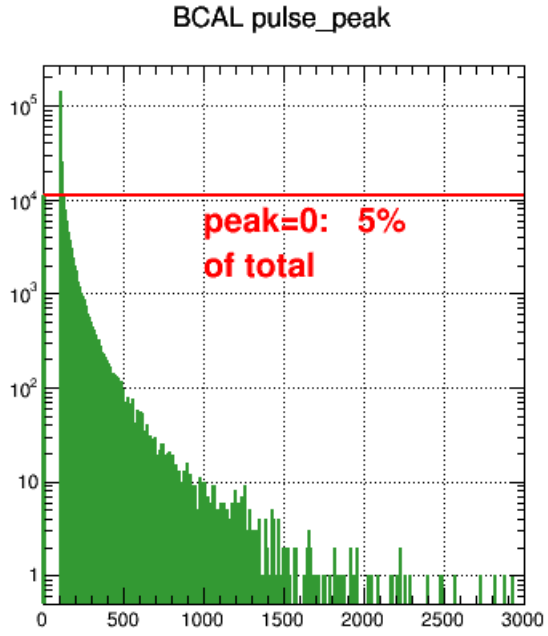
Hits outside of the shaded areas were dropped before writing out the reconstituted EVIO file

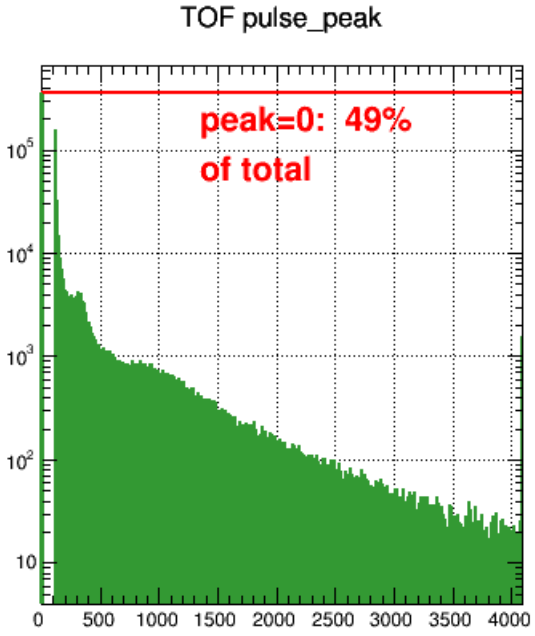
Cuts made on fully calibrated times. Cuts done in modules will be on uncalibrated times

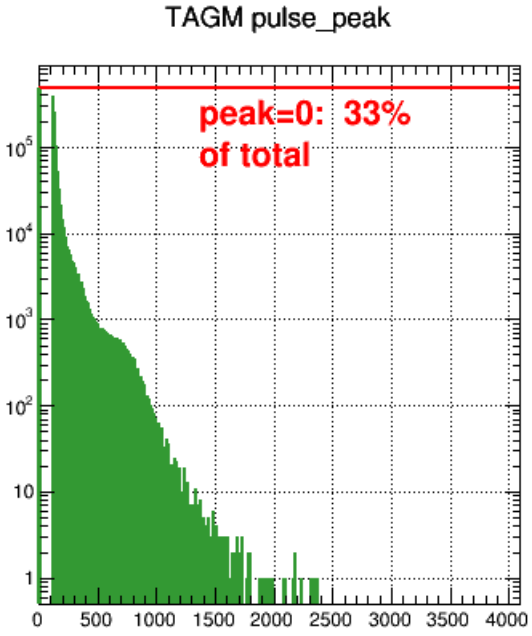


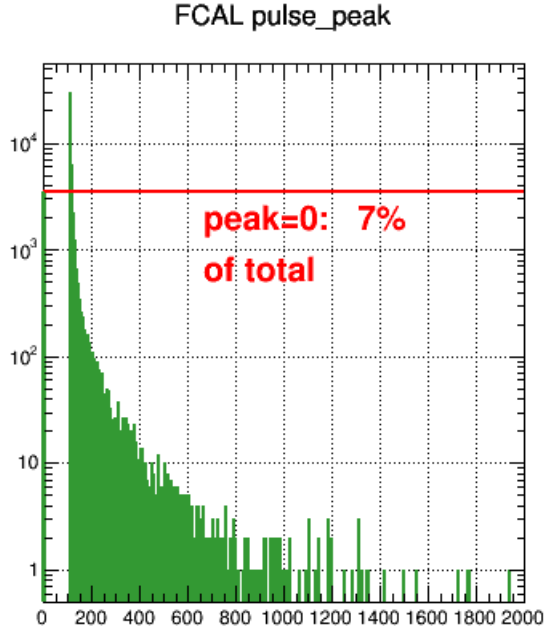


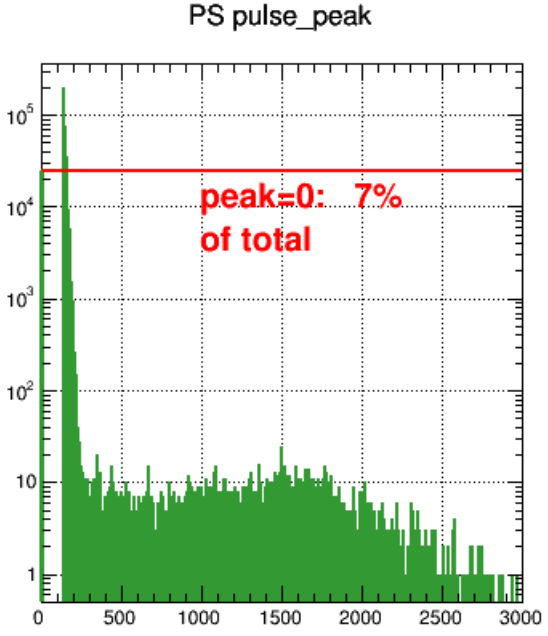


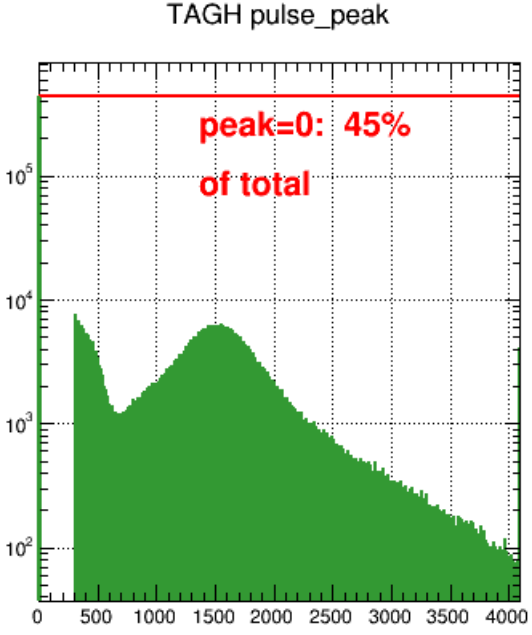

BCAL pulse_peak
peak=0: 5%
of total


TOF pulse_peak
peak=0: 49%
of total


TAGM pulse_peak
peak=0: 33%
of total


FCAL pulse_peak
peak=0: 7%
of total


PS pulse_peak
peak=0: 7%
of total


TAGH pulse_peak
peak=0: 45%
of total

Reconstruction times survey

Time is divided by #calls and #threads

J1A50 50 um radiator, PERP, 7 mode, 105 nA beam current, 27 kHz event rate, live time ~70% , LH2 fill, 5 mm collimator, 83 M total events

hd_rawdata_010913_060.

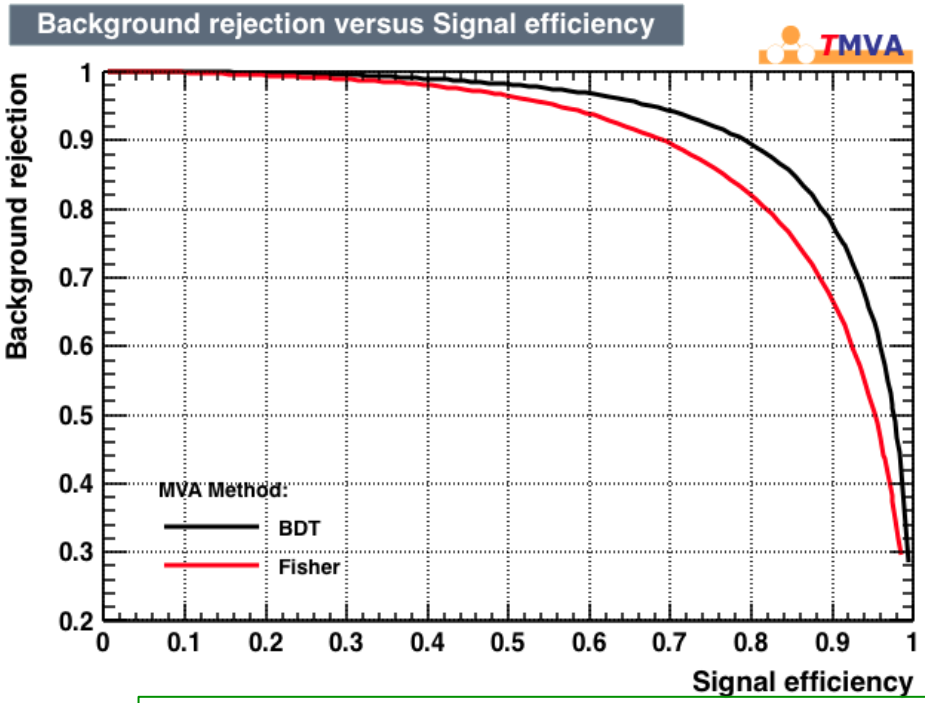
input file: phys_skim.evio

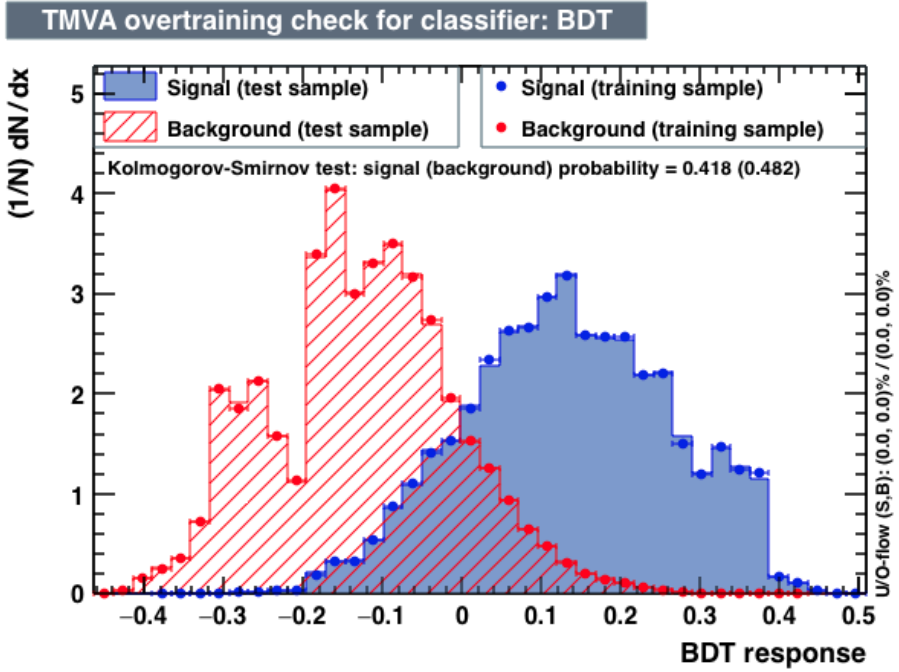
events	ALGORITHM	INPUT OBJECT	RECO TIME [s]	RECO TIME/event [ms]
10000	nominal reco	DNeutralShower	4.410	**0.028**
DATA	approx reco	DBCALShower	2.750	**0.017**
	approx reco	DFCALShower	8.010	**0.050**
	full tracking	DTrackTimeBased	18669.810	**116.69**
	approx tracking	DTrackWireBased	7397.300	**46.23**

hdgeant_smeared_14980

events	ALGORITHM	INPUT OBJECT	RECO TIME [s]	RECO TIME/event [ms]
10000	nominal reco	DNeutralShower	5.730	**0.036**
MC	approx reco	DBCALShower	3.430	**0.021**
	approx reco	DFCALShower	7.010	**0.044**
	full tracking	DTrackTimeBased	23878.840	**149.243**
	approx tracking	DTrackWireBased	12778.340	**79.865**

n.b. parsing of evio data takes 0.080 – 0.400 ms/event






```
--- BDT              : Ranking result (top variable is best ranked)
--- BDT              : ----------------------------------------------
--- BDT              : Rank : Variable        : Variable Importance
--- BDT              : ----------------------------------------------
--- BDT              :    1 : Efcal_clusters    : 1.917e-01
--- BDT              :    2 : Ntrack_candidates : 1.710e-01
--- BDT              :    3 : Nfcal_clusters    : 1.279e-01
--- BDT              :    4 : Nbcal_points      : 1.258e-01
--- BDT              :    5 : Npshits           : 8.291e-02
--- BDT              :    6 : Ebcal_points      : 7.186e-02
--- BDT              :    7 : Ebcal_clusters    : 6.445e-02
--- BDT              :    8 : Ntof              : 6.424e-02
--- BDT              :    9 : Nstart_counter    : 5.138e-02
--- BDT              :   10 : Nbcal_clusters    : 4.873e-02
--- BDT              :   11 : Ptot_candidates   : 0.000e+00
--- BDT              :   12 : Npschits          : 0.000e+00
```

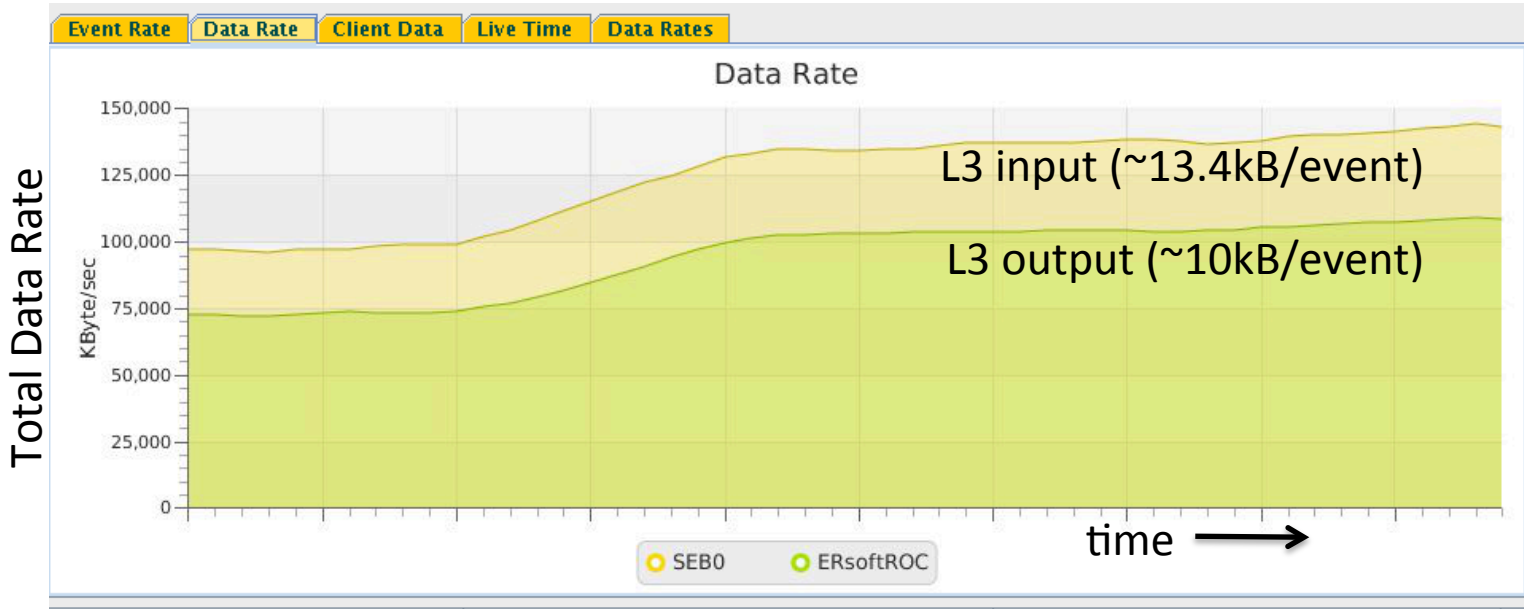
Spring 2016 data

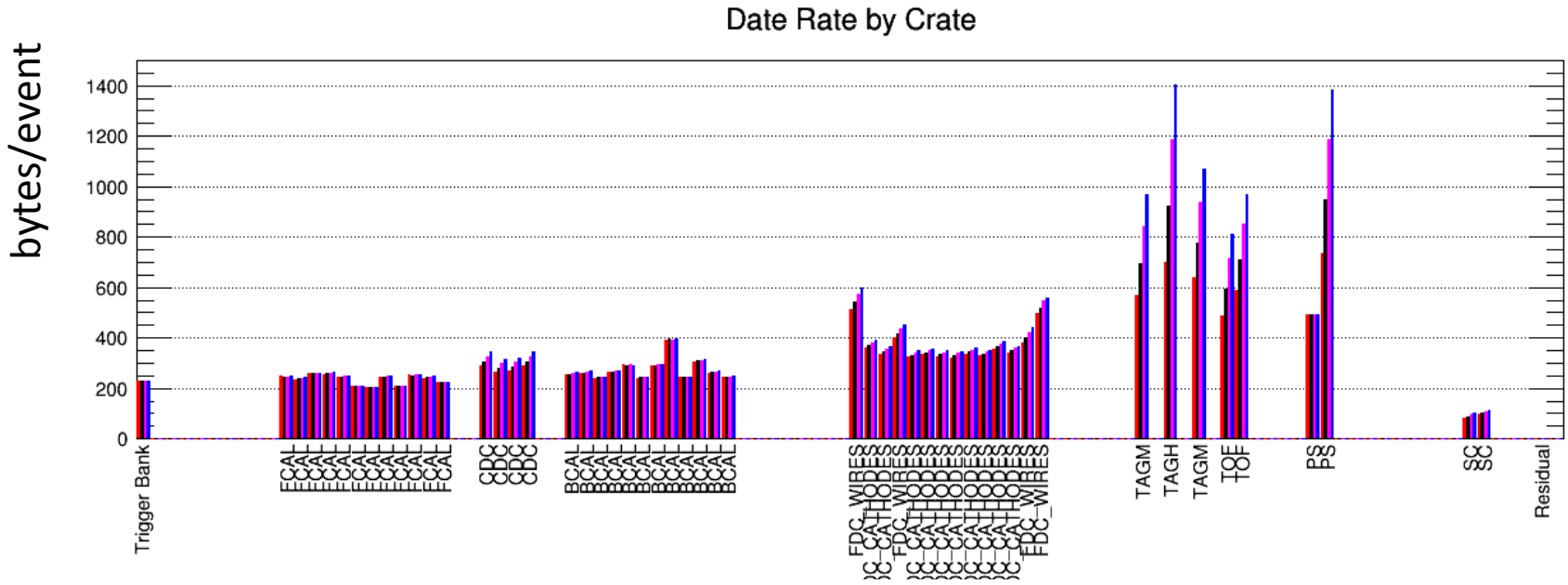
$HALLD_HOME/src/plugins/Utilities/l3bdt

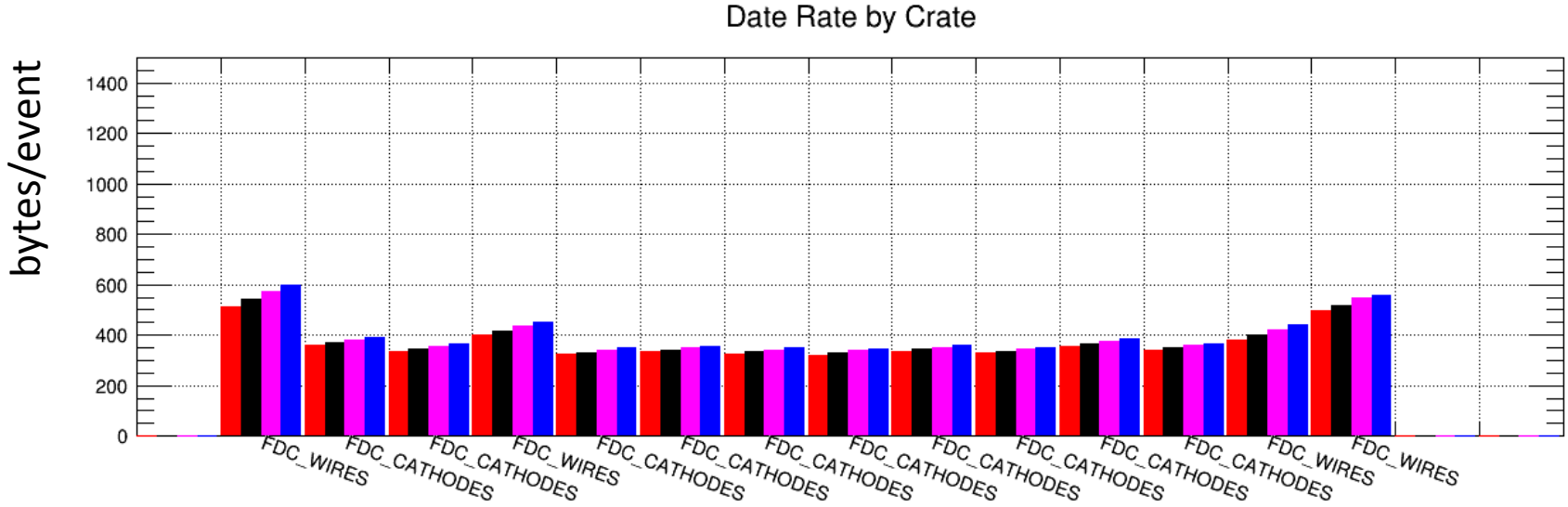
- "signal" events had >**4GeV** of fully reconstructed energy*

L3 running in pass-through with beam

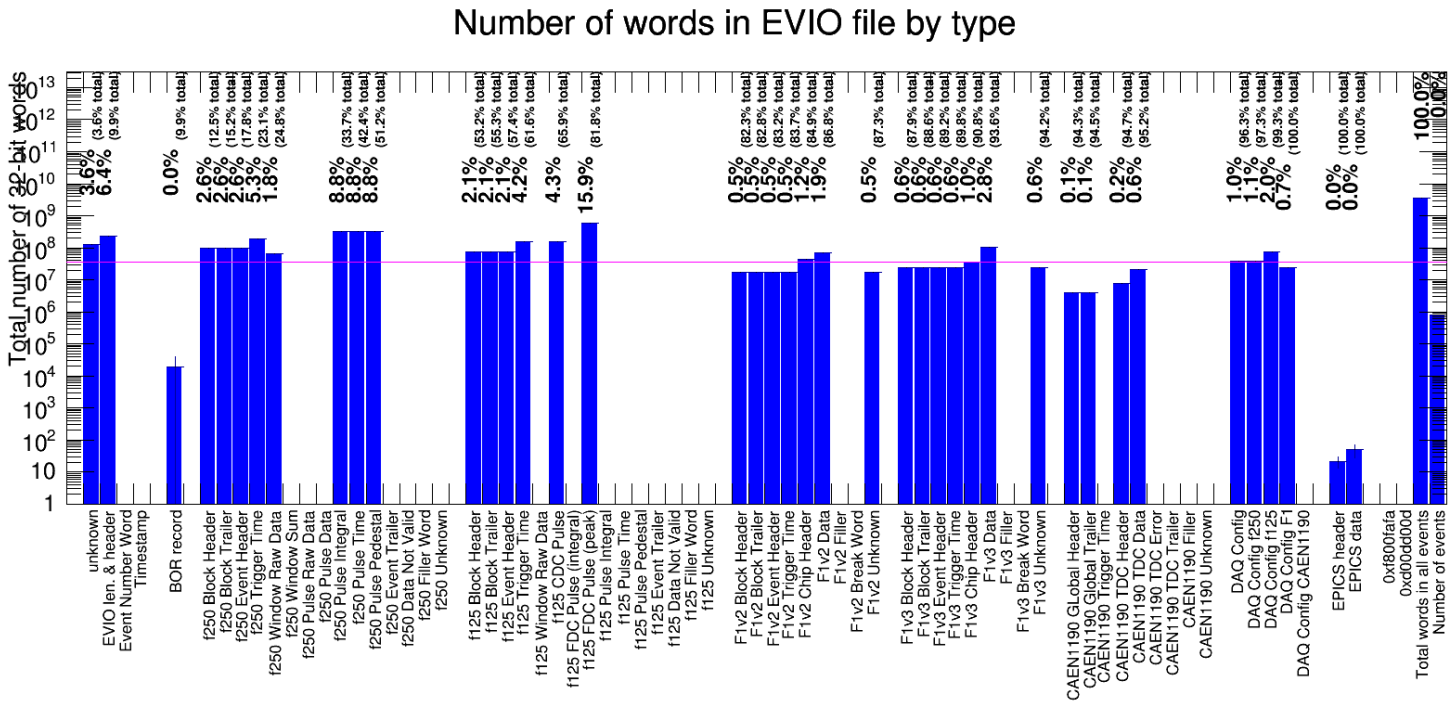
- Events are read in blocks of 20
- Events must be disentangled and reconstituted as single events before writing to disk
- Redundant headers may be dropped to reduce event size



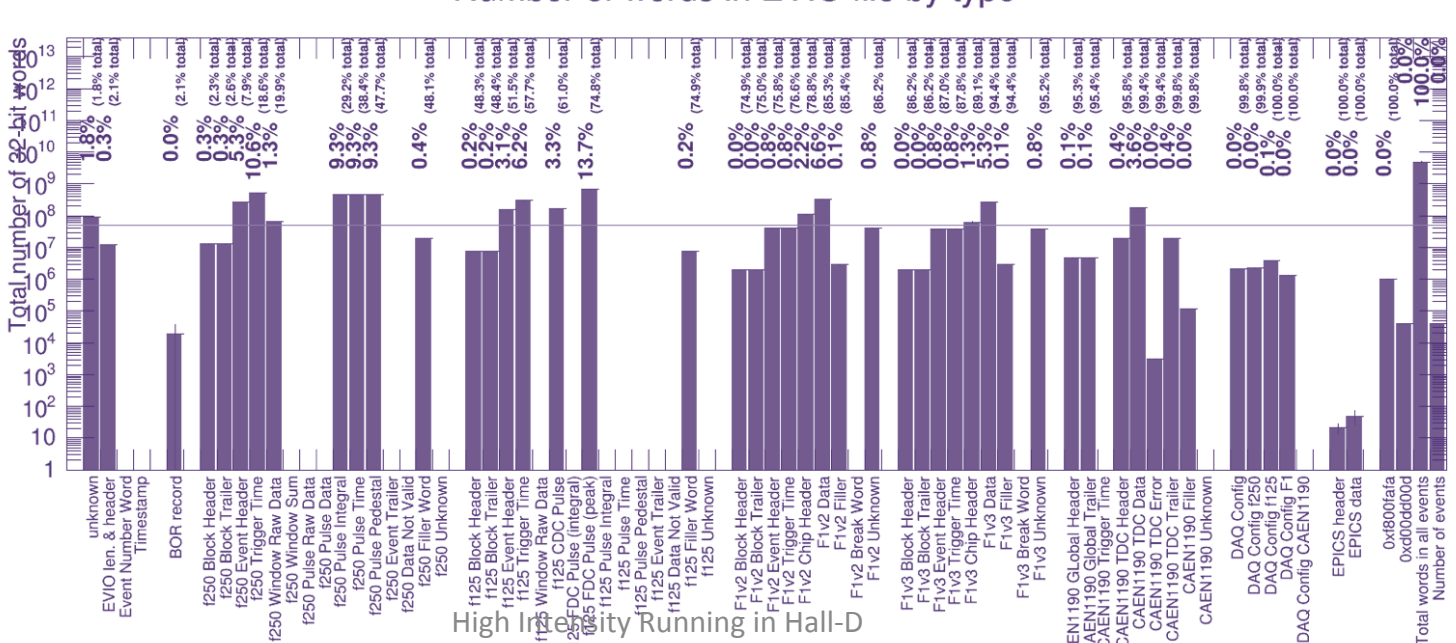

Date Rate by Crate
August 18, 2016 DL
bytes/event
1400
1200
1000
800
600
400
200
0
Trigger Bank
FCAL
CDC
BCAL
FDC_WIRES
TAGM
TAGH
TOF
PS
SC
Residual


Date Rate by Crate
bytes/event
1400
1200
1000
800
600
400
200
0
FDC_WIRES
FDC_CATHODES
FDC_WIRES
FDC_WIRES

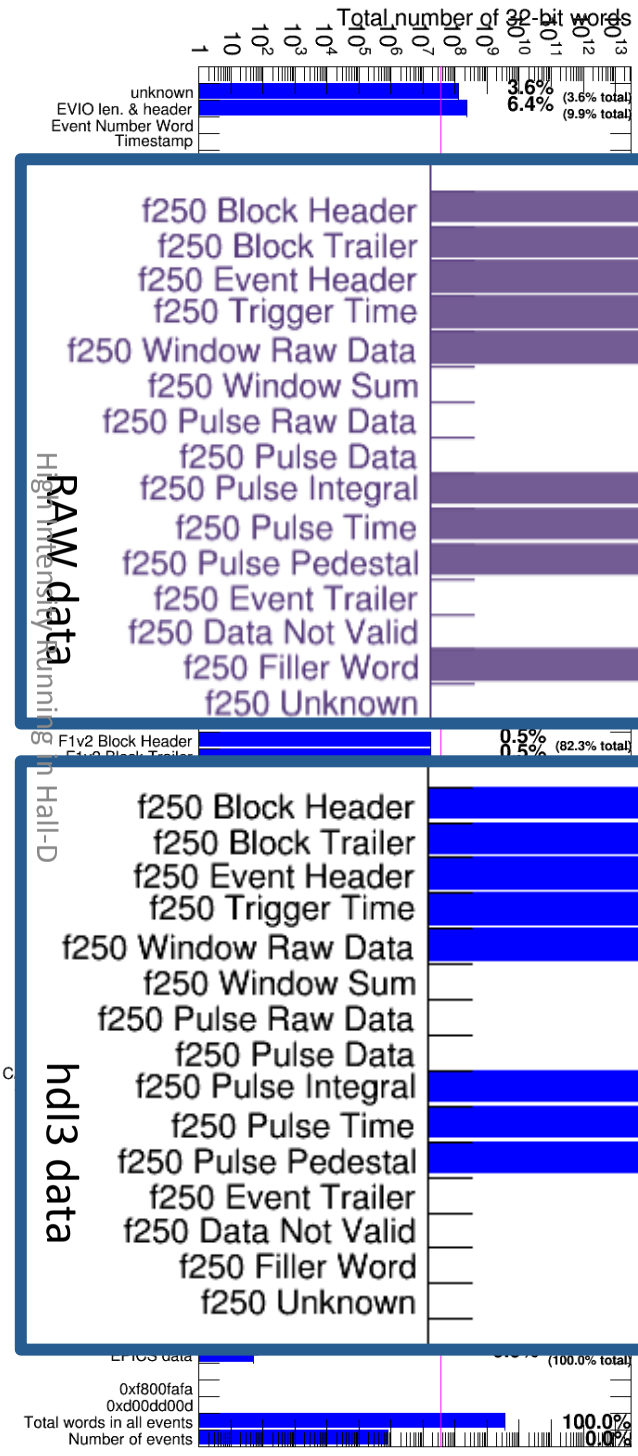
RAW data



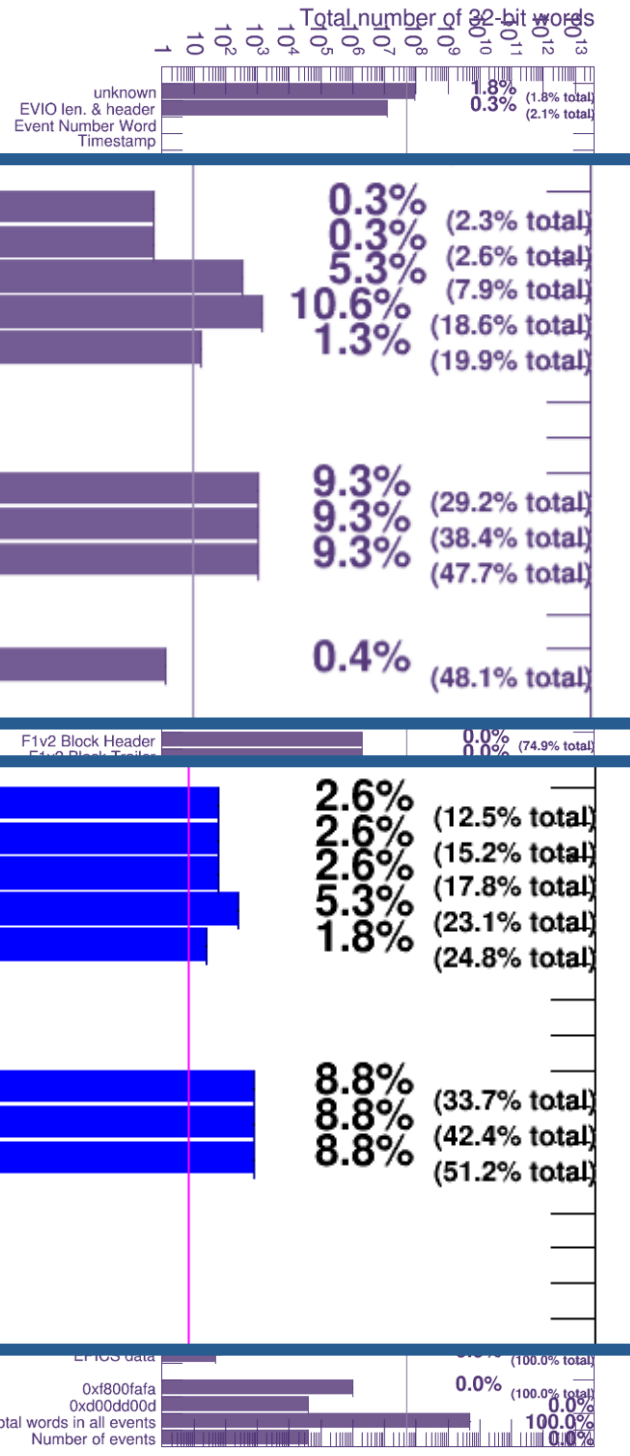
Hdl3 data

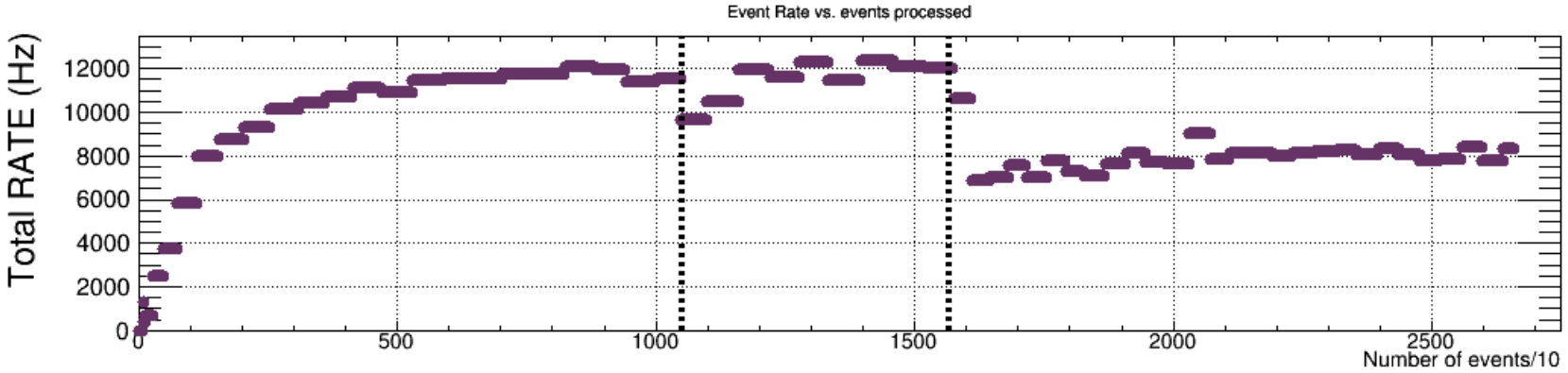


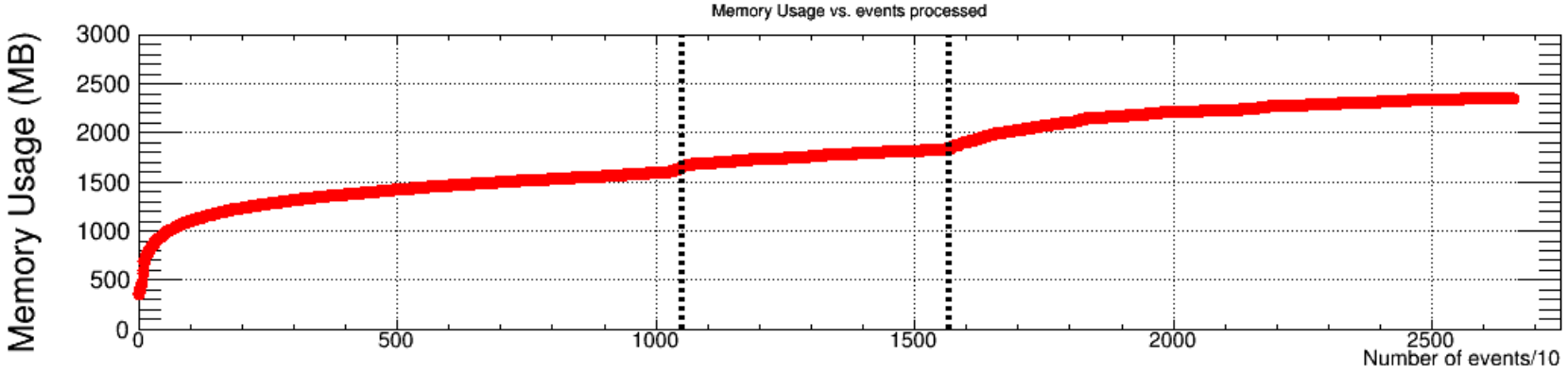
hdl3 data

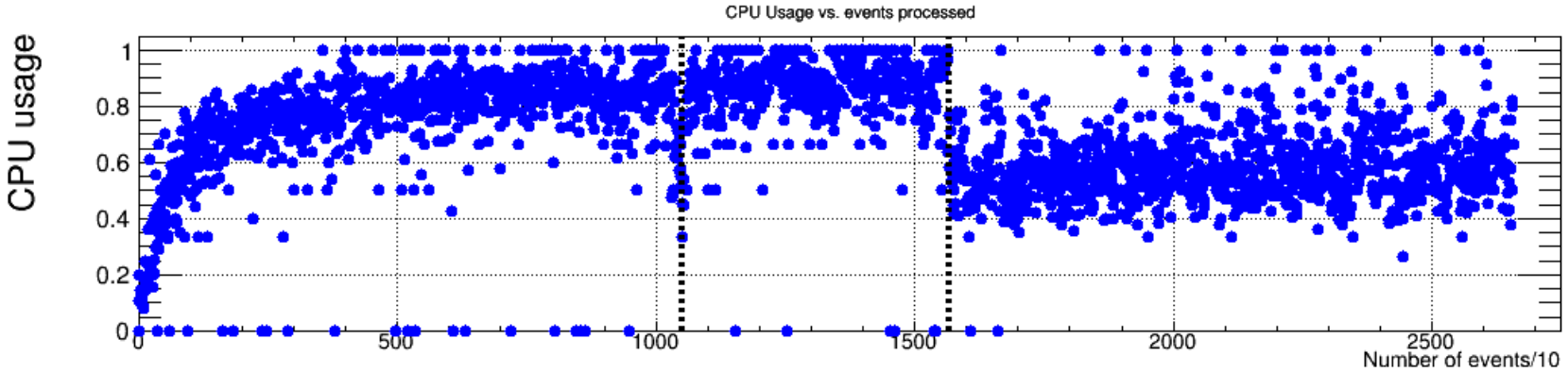


RAW data




Event Rate vs. events processed
Total RATE (Hz)
0
2000
4000
6000
8000
10000
12000
0
500
1000
1500
2000
2500
Number of events/10

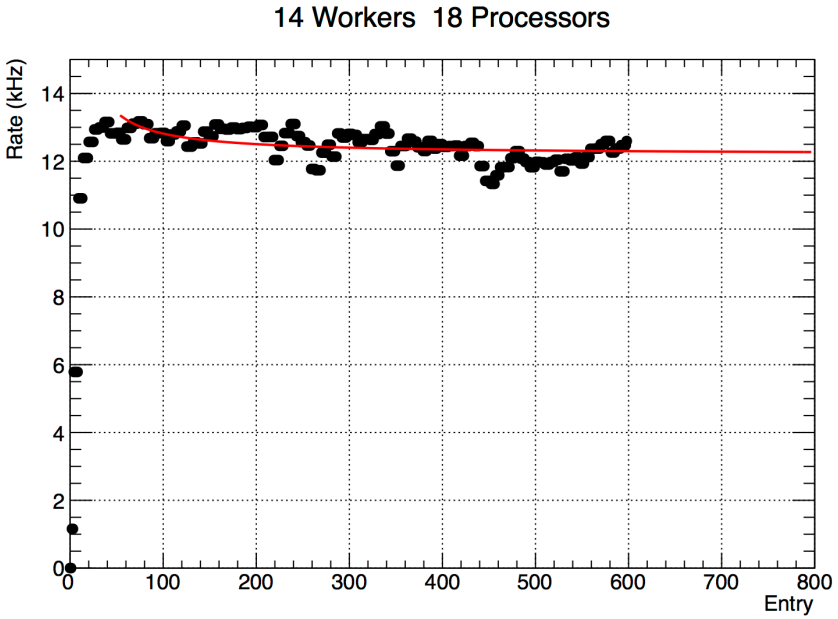

Memory Usage vs. events processed
Memory Usage (MB)
0
500
1000
1500
2000
2500
3000
0
500
1000
1500
2000
2500
Number of events/10

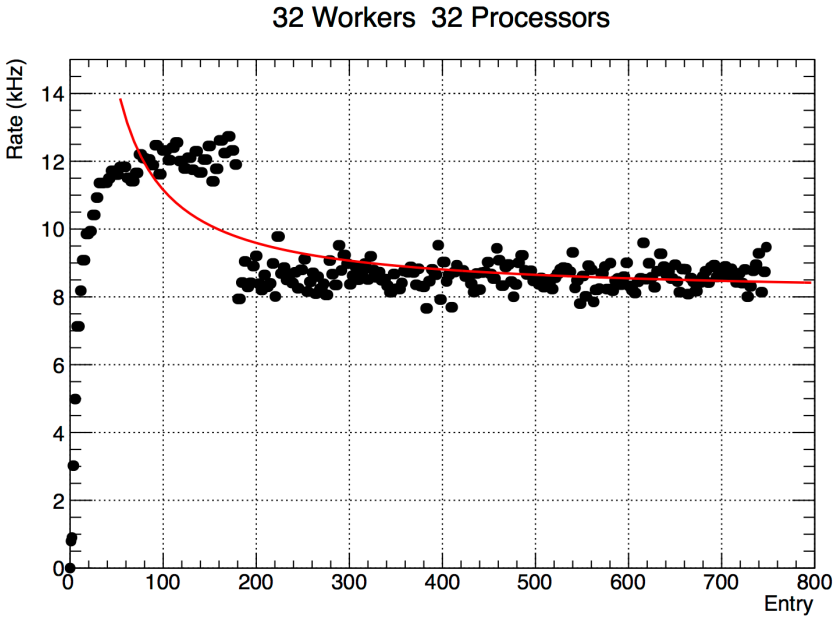

CPU Usage vs. events processed
CPU usage
0
0.2
0.4
0.6
0.8
1
0
500
1000
1500
2000
2500
Number of events/10

Fitting event rate vs. time

$$R(t) = R_o(1 + Q/t)$$

R_o = asymptotic rate
Q = relaxation term

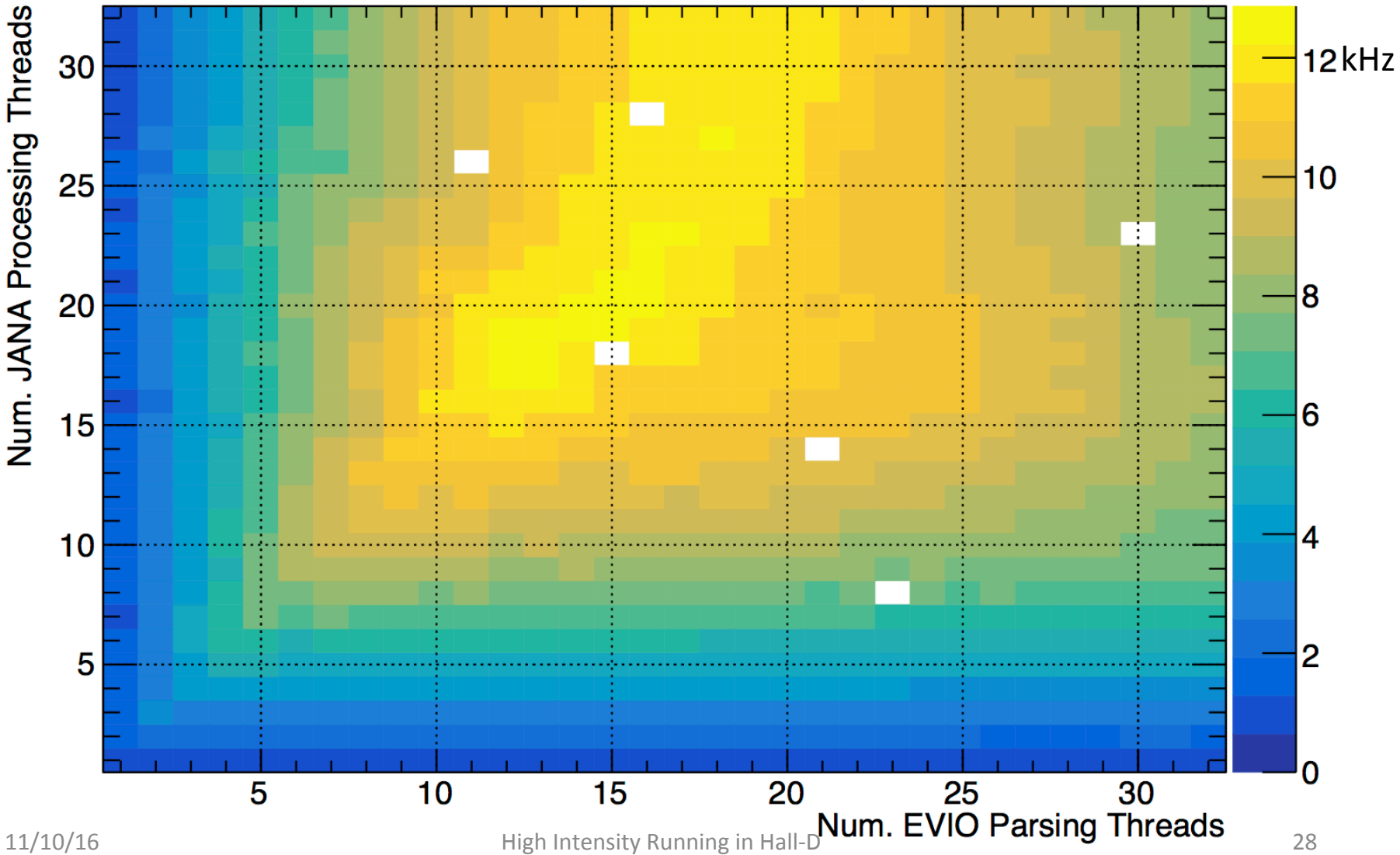


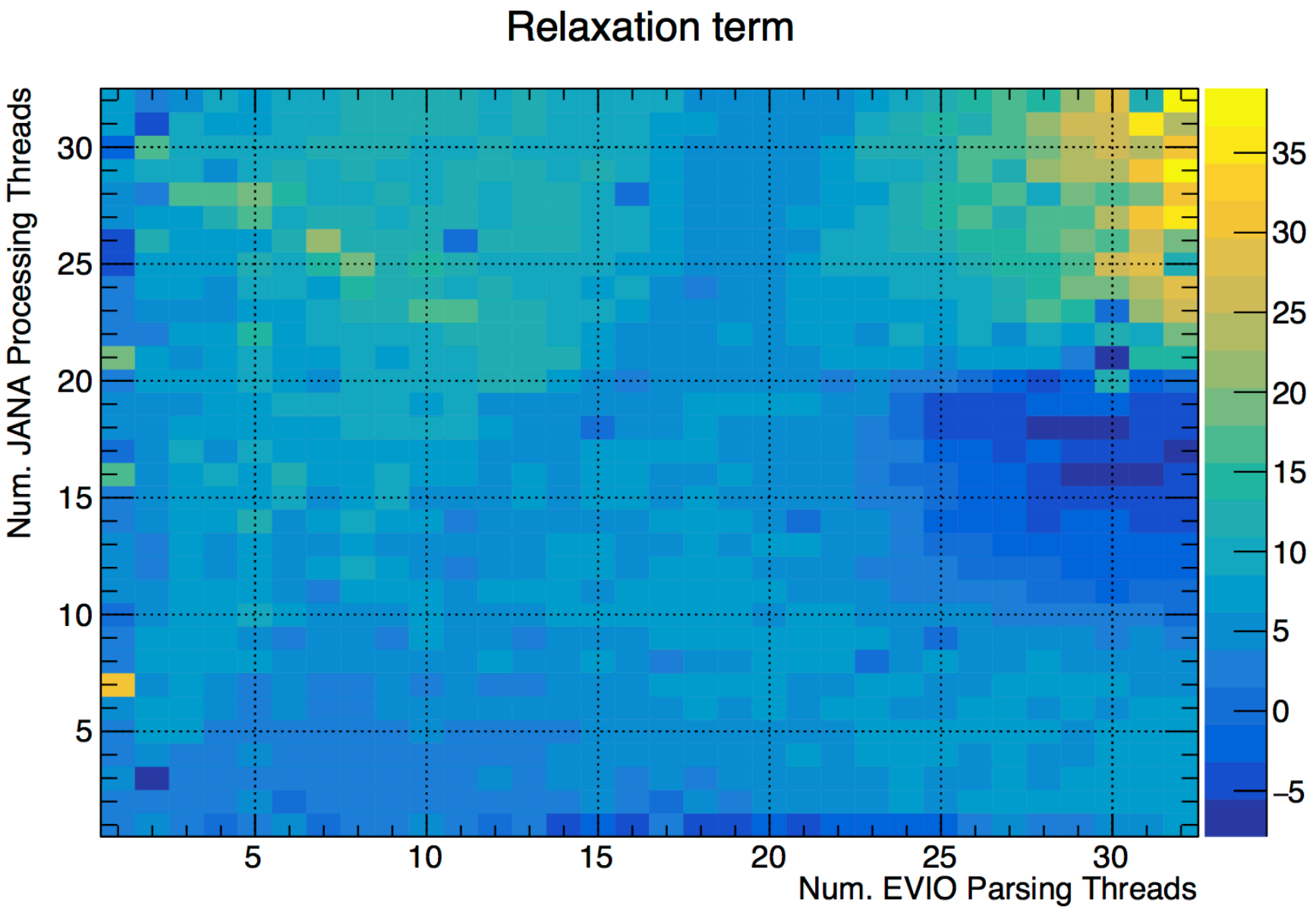


Parsing only

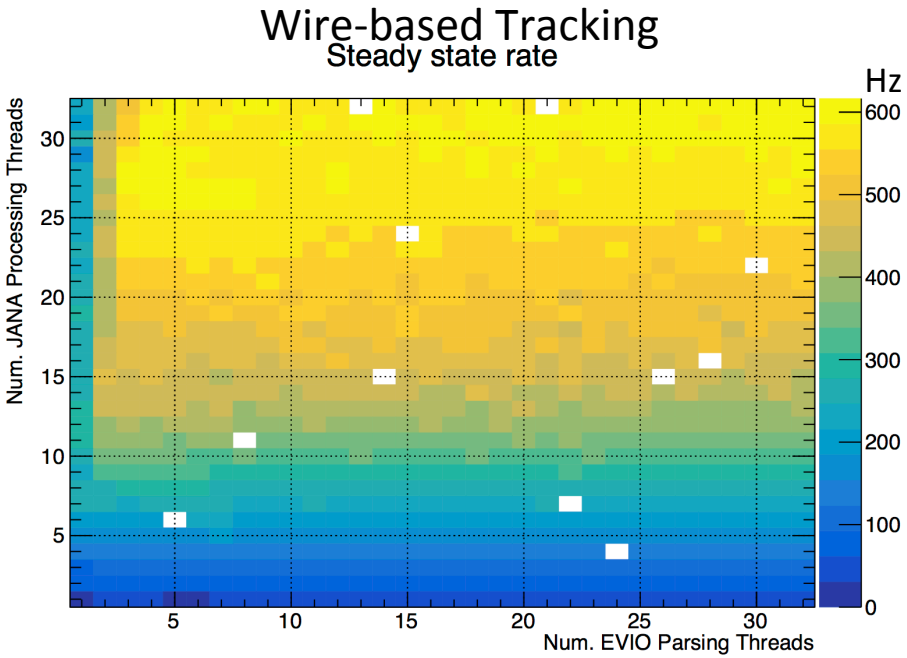
(no linking, no reconstruction)

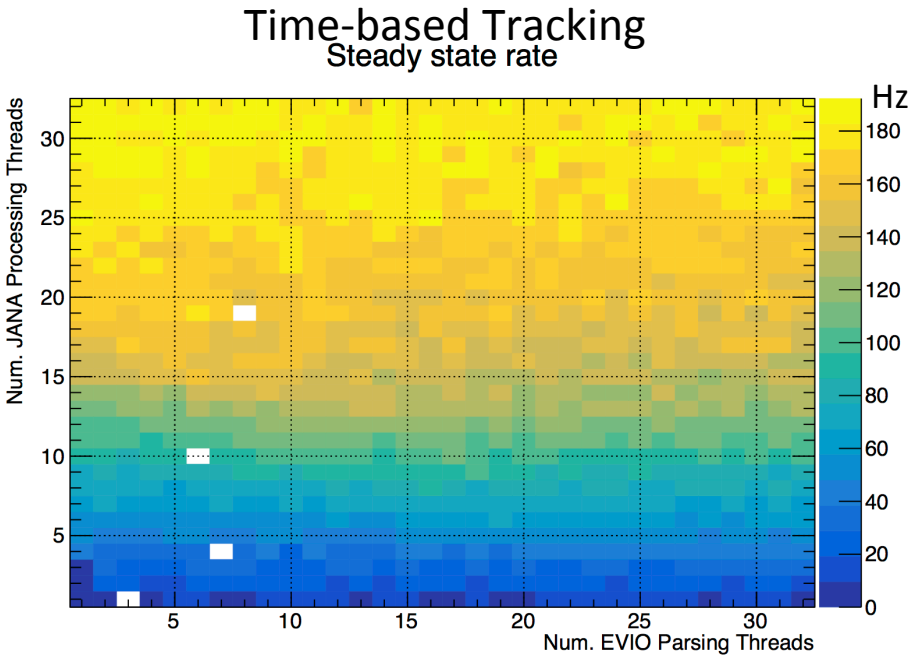
Steady state rate




Relaxation term
Num. JANA Processing Threads
30
25
20
15
10
5
5
10
15
20
25
30
Num. EVIO Parsing Threads
35
30
25
20
15
10
5
0
−5

Event rates with tracking

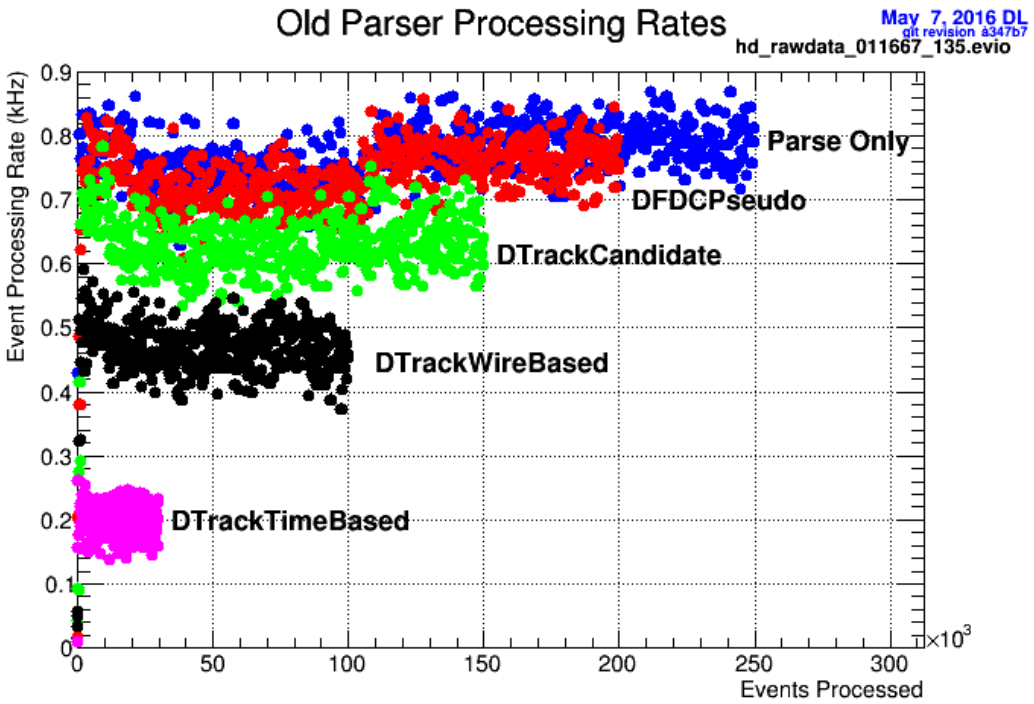


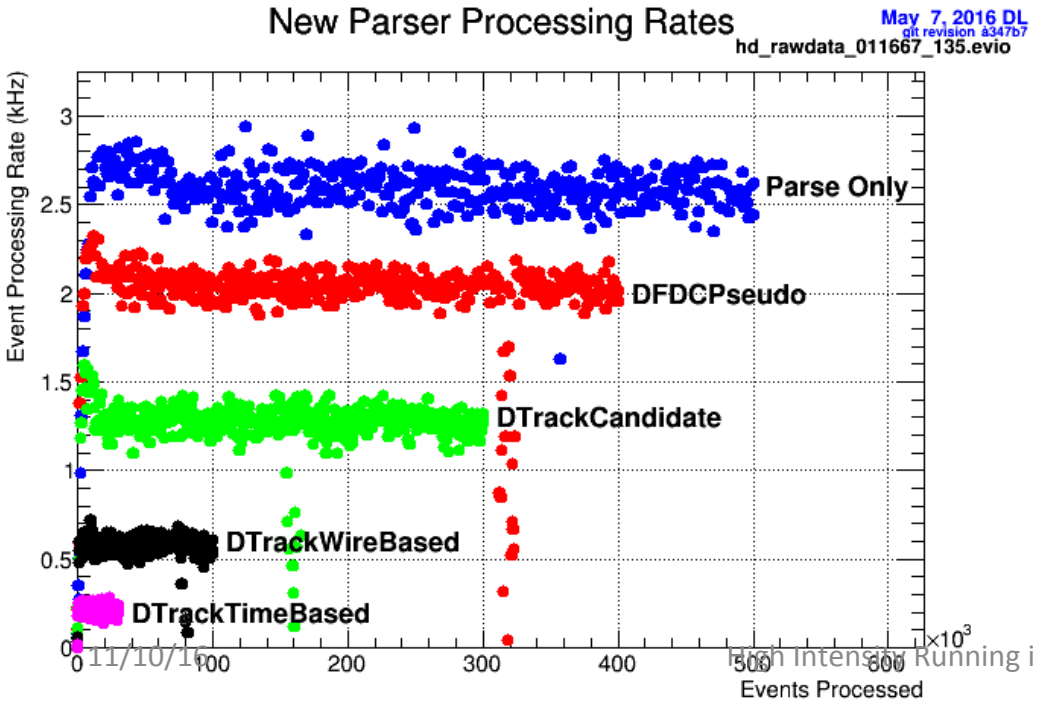


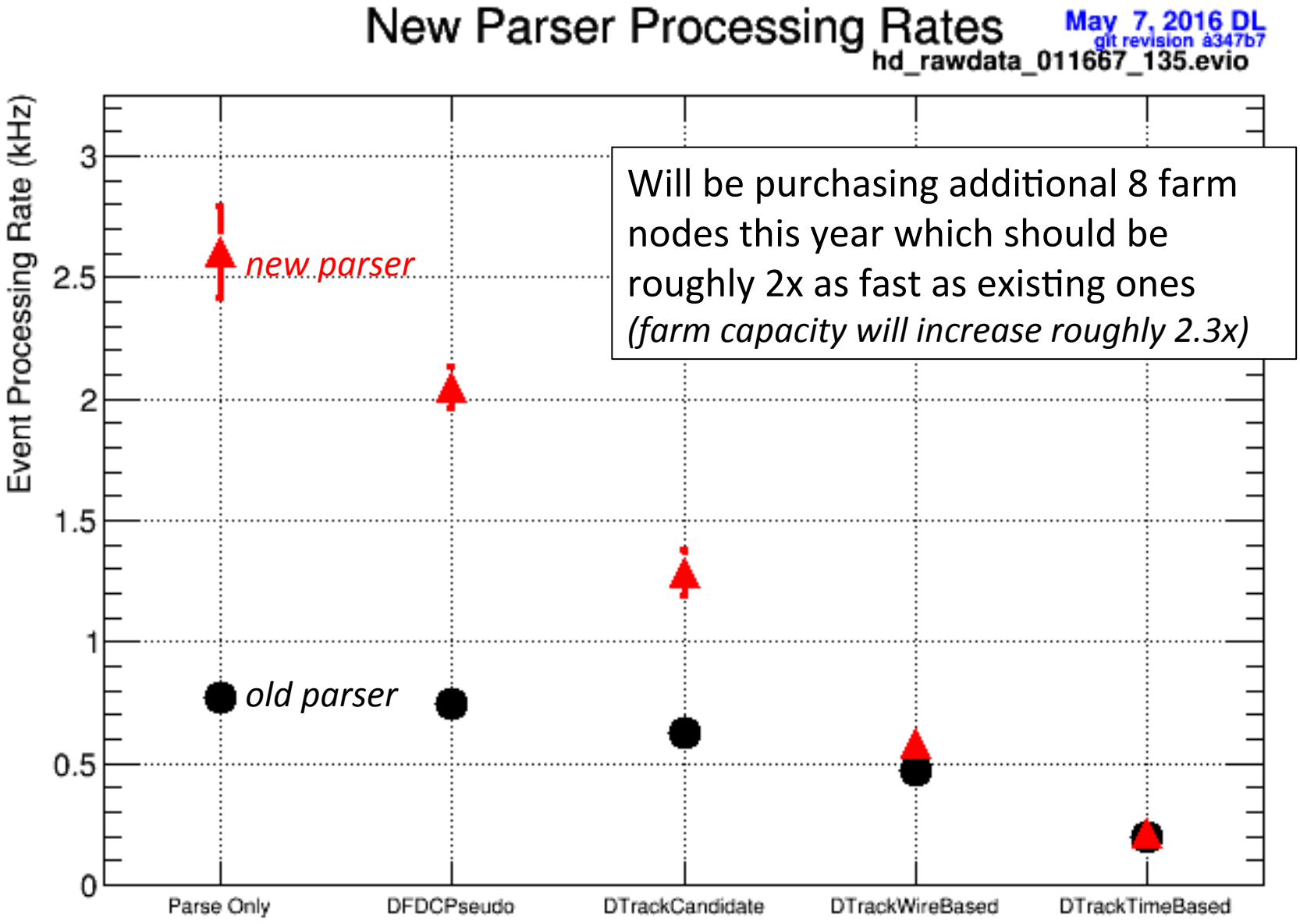
- With associated object linking, parsing threads run about 4 times slower
- Single parsing thread with full linking: ~250Hz

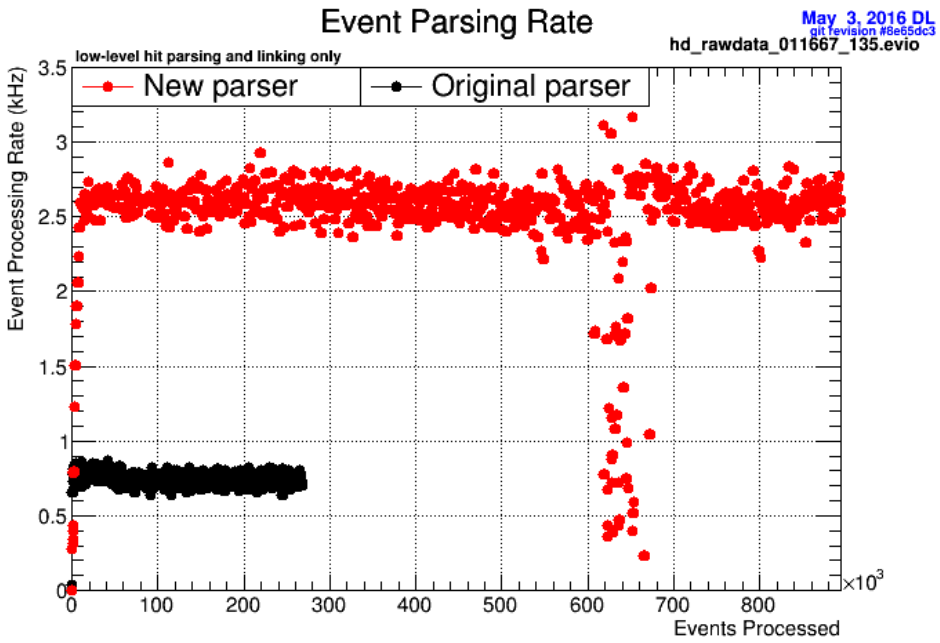
EVIO Parsing Time

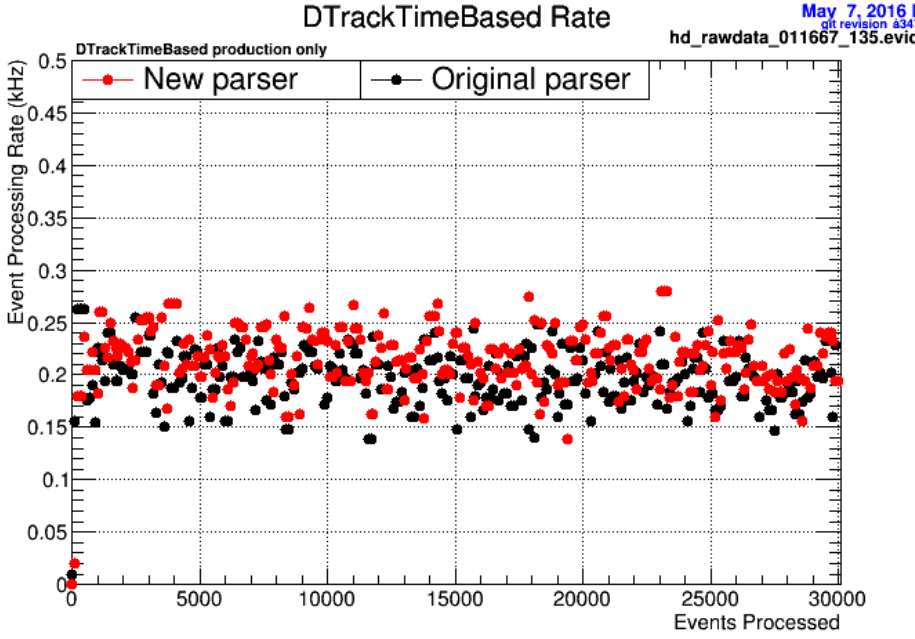
Rate (kHz)	Time/core/event (ms)	Condition
2.5	8.0	All linking enabled
2.9	6.9	All linking except TriggerTime
3.8	5.3	All linking except BORConfig
3.0	6.7	All linking except Config
4.8	4.2	All linking except TriggerTime and BORConfig
5.9	3.4	Hit linking only
8.0	2.5	No Linking

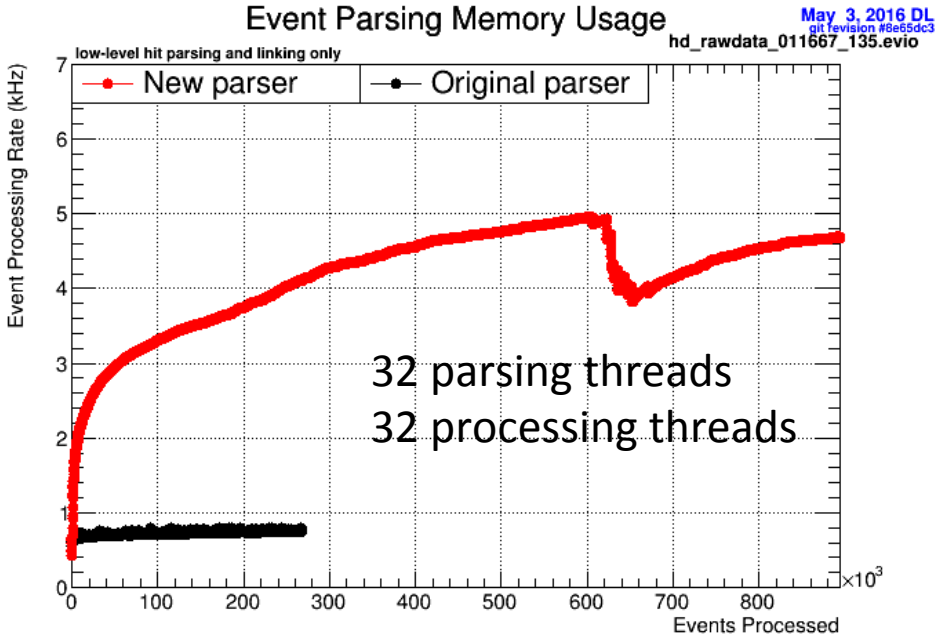

Old Parser Processing Rates
May 7, 2016 DL
git revision a347b7
hd_rawdata_011667_135.evio
Event Processing Rate (kHz)
Events Processed
×10^3
Parse Only
DFDCPseudo
DTrackCandidate
DTrackWireBased
DTrackTimeBased

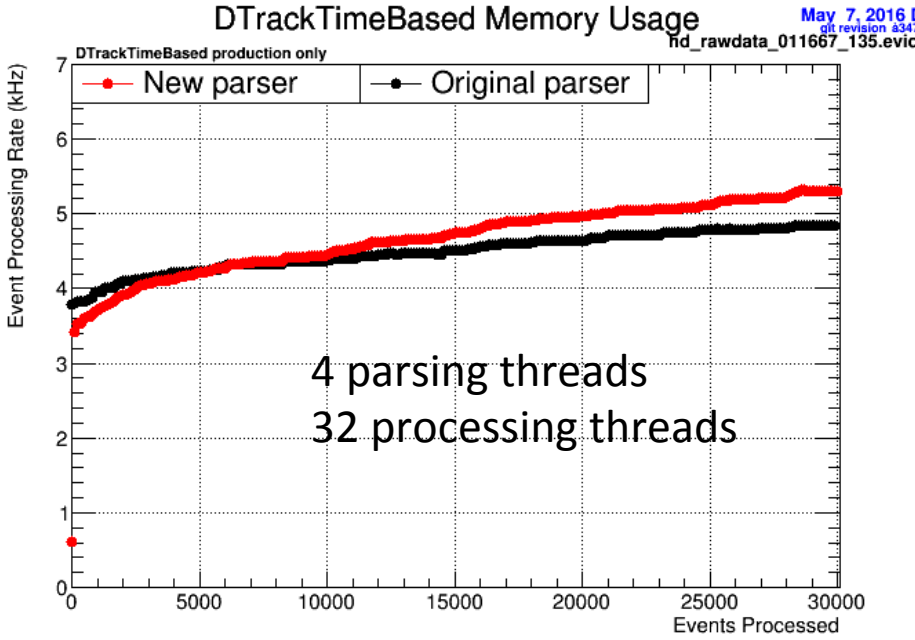

New Parser Processing Rates
May 7, 2016 DL
git revision a347b7
hd_rawdata_011667_135.evio
Event Processing Rate (kHz)
Events Processed
×10^3
Parse Only
DFDCPseudo
DTrackCandidate
DTrackWireBased
DTrackTimeBased

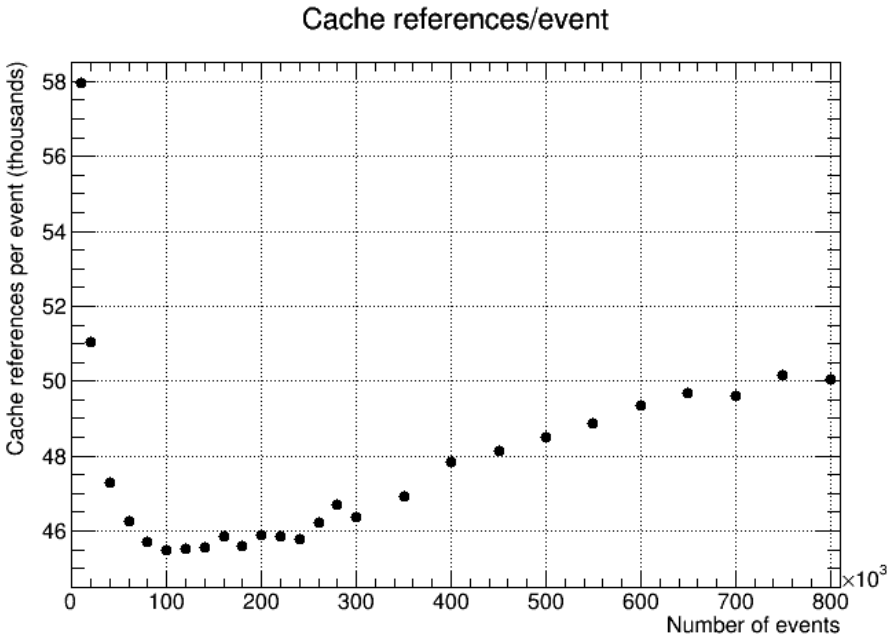

New Parser Processing Rates
May 7, 2016 DL
git revision a347b7
hd_rawdata_011667_135.evio
Event Processing Rate (kHz)
3
2.5
2
1.5
1
0.5
0
new parser
old parser
Will be purchasing additional 8 farm nodes this year which should be roughly 2x as fast as existing ones
(farm capacity will increase roughly 2.3x)
Parse Only
DFDCPseudo
DTrackCandidate
DTrackWireBased
DTrackTimeBased

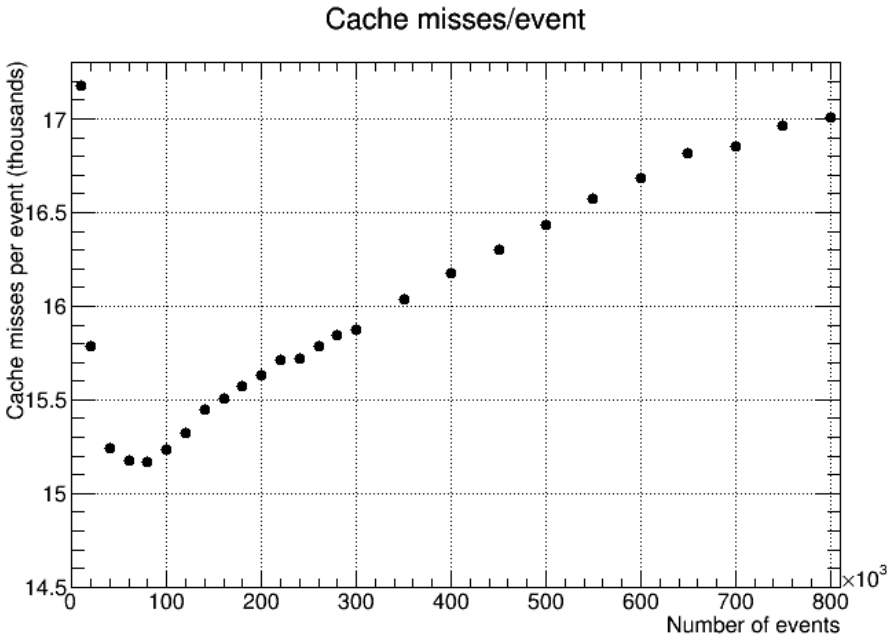

Event Parsing Rate
May 3, 2016 DL
git revision #8e65dc3
hd_rawdata_011667_135.evio
low-level hit parsing and linking only
New parser
Original parser
Event Processing Rate (kHz)
Events Processed
×10³

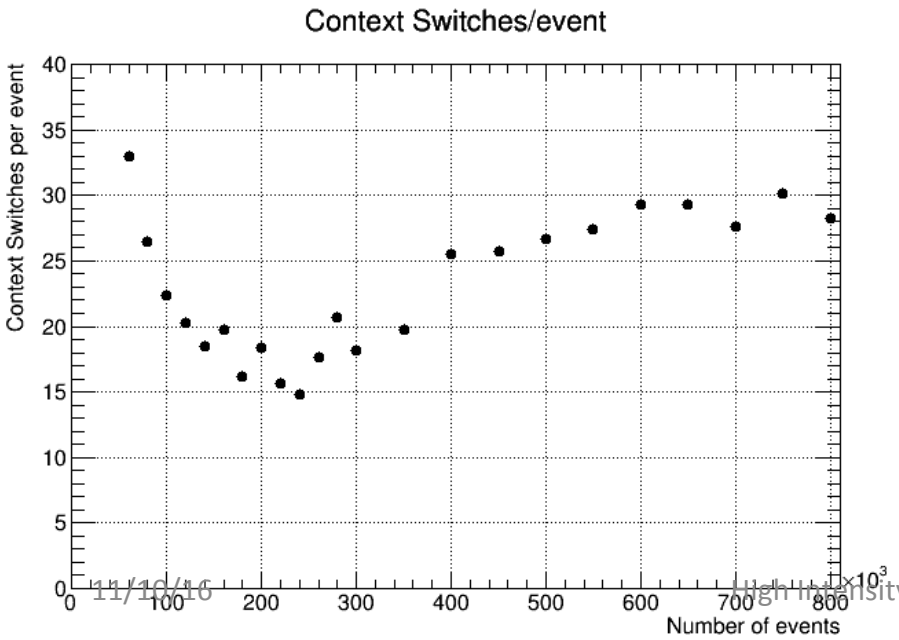

DTrackTimeBased Rate
May 7, 2016 DL
git revision a347b7
hd_rawdata_011667_135.evio
DTrackTimeBased production only
New parser
Original parser
Event Processing Rate (kHz)
Events Processed

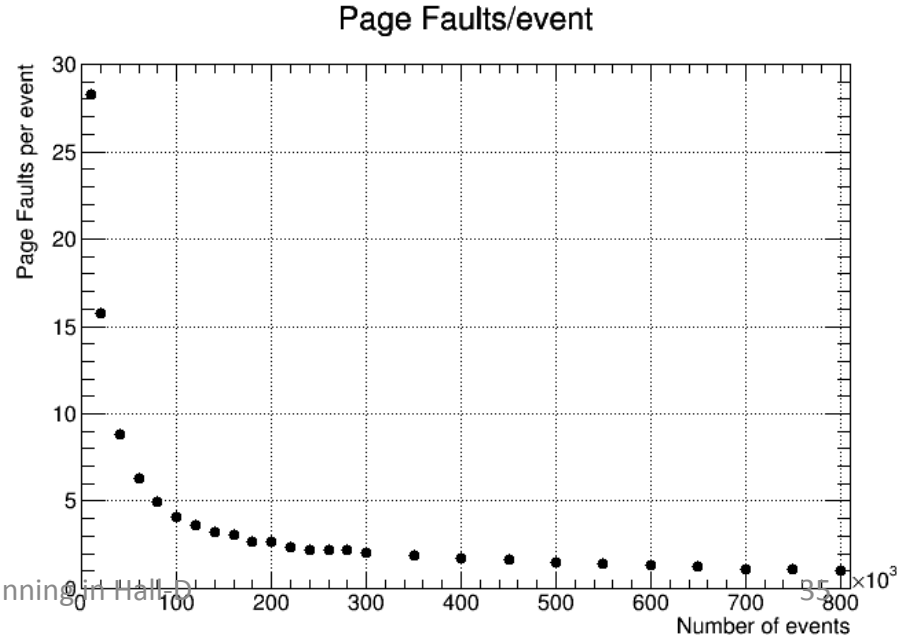

Event Parsing Memory Usage
May 3, 2016 DL
git revision #8e65dc3
hd_rawdata_011667_135.evio
low-level hit parsing and linking only
New parser
Original parser
Event Processing Rate (kHz)
Events Processed
×10³
32 parsing threads
32 processing threads


DTrackTimeBased Memory Usage
May 7, 2016 DL
git revision a347b7
hd_rawdata_011667_135.evio
DTrackTimeBased production only
New parser
Original parser
Event Processing Rate (kHz)
Events Processed
4 parsing threads
32 processing threads


Cache references/event
Cache references per event (thousands)
Number of events
×10³

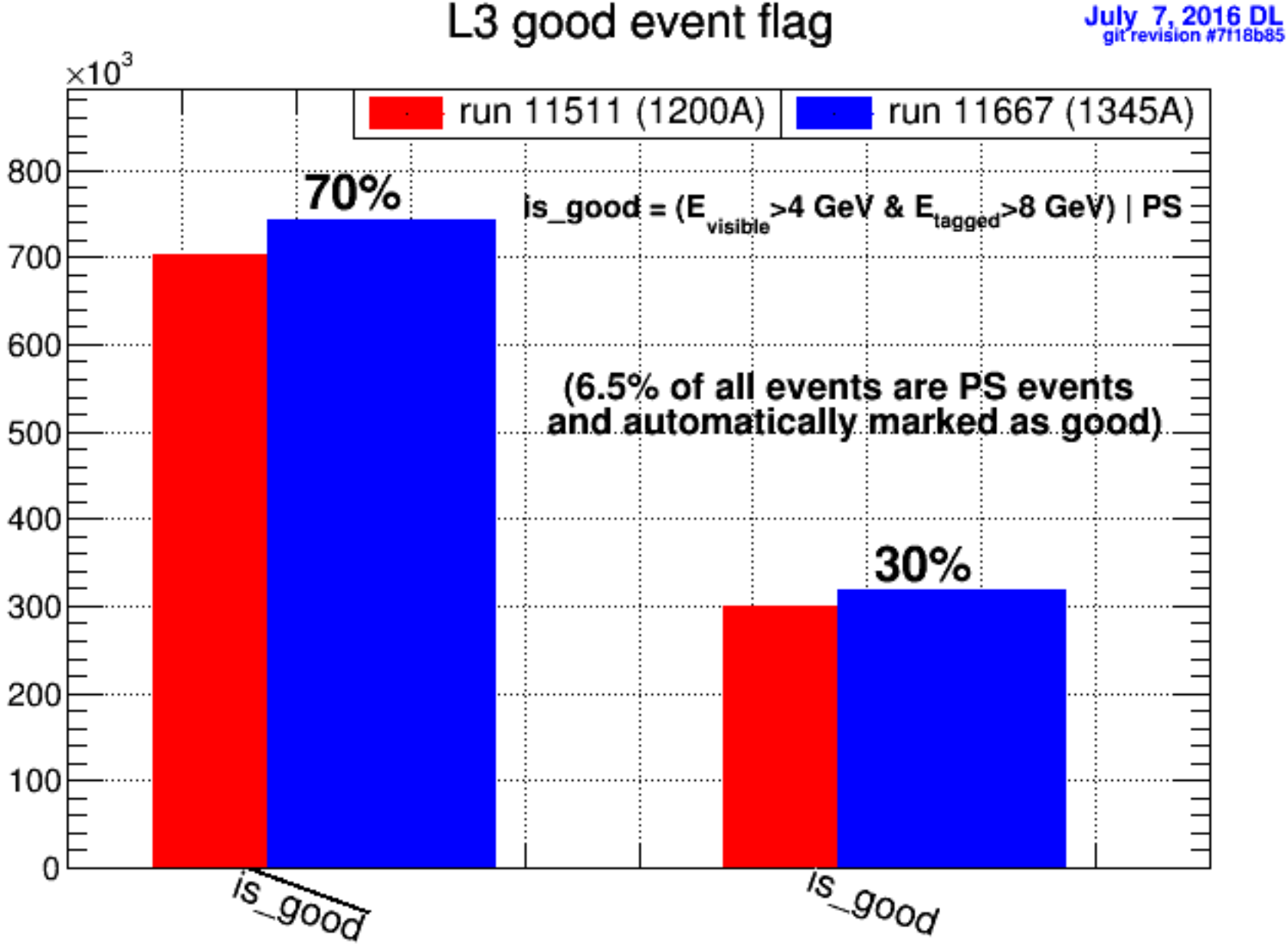

Cache misses/event
Cache misses per event (thousands)
Number of events
×10³


Context Switches/event
Context Switches per event
Number of events
×10³


Page Faults/event
Page Faults per event
Number of events
×10³

Input Test File

- hd_rawdata_011667_135.evio
  - 120nA, 50μm diamond (PERP), 5.0mm collimator
  - $I_{solenoid}$ = 1345A
  - 18kB/event
  - Measured I/O rate: ~900MB/s (=50kHz)
    - fspeed_reader
    - gluonraid2 -> gluon48
  - Maximum sim-recon read speed: ~33kHz
    - Parsing and linking disabled

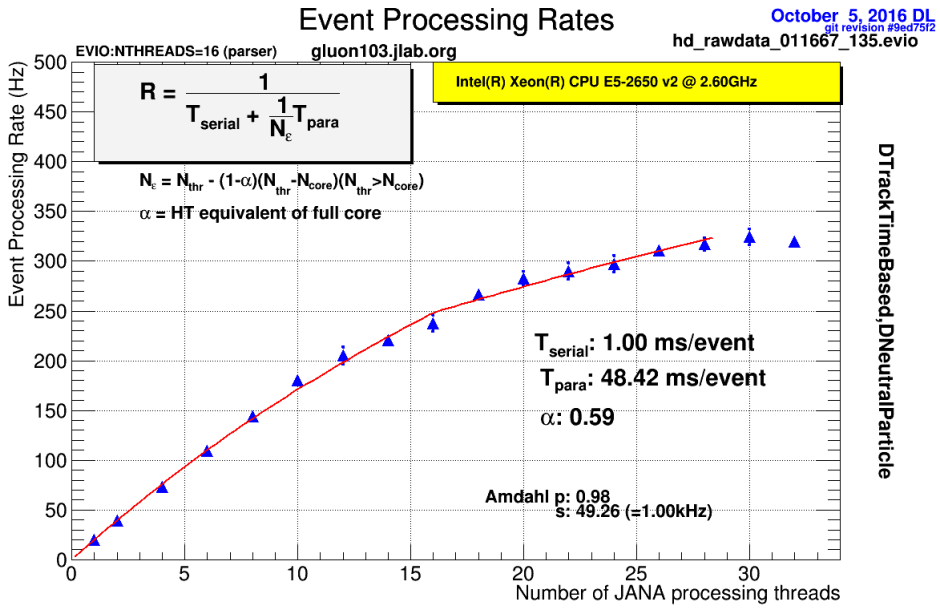

L3 good event flag
July 7, 2016 DL
git revision #7f18b85
×10^3
run 11511 (1200A)
run 11667 (1345A)
800
700
600
500
400
300
200
100
0
70%
is_good = (E visible >4 GeV & E tagged >8 GeV) | PS
(6.5% of all events are PS events
and automatically marked as good)
30%
is_good
is_good

Counting house computer systems

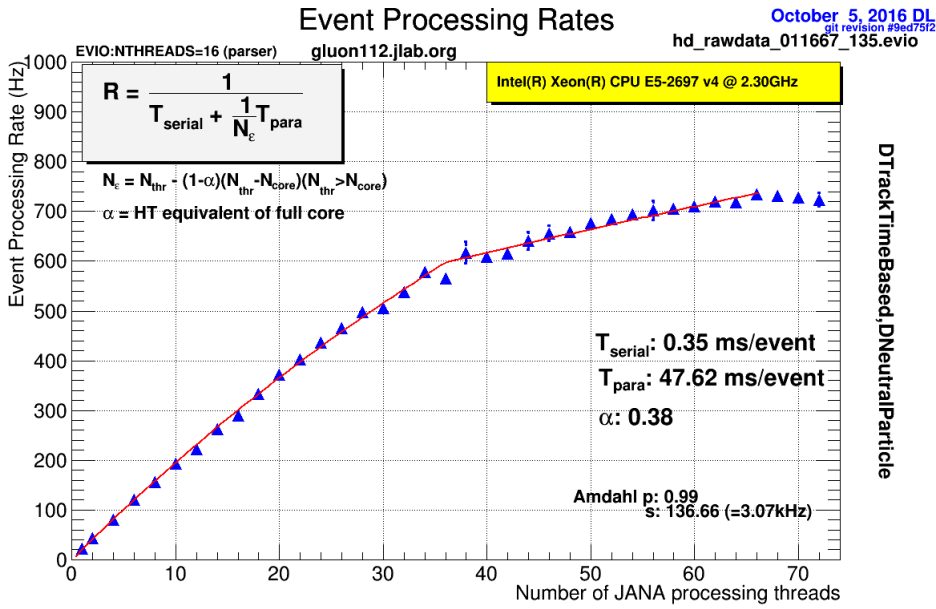
Computer(s)	processor	General Purpose Network	DAQ Network	I.B. Network	comments
gluonfs1	N/A	X			~1.6TB with snapshot backup
gluonraid1-2	Intel E5-2630 v2 @2.6GHz	X	X	X	RAID disk host ER process
gluon01-05	i5-3570 @3.4GHz	X			Shift taker consoles
gluon20-23	AMD 2347	X			Controls 8core
gluon24-30	E5-2420 @1.9GHz	X			Controls (gluon24 is web/DB/cMsg server) 12core + 12ht
gluon40-43	AMD 6380	X	X	X	16core + 16"ht"
gluon46-49	E5-2650 v2 @2.6GHz	X	X (gluon47 &49)	X	16core + 16ht
gluon100-111	E5-2650 v2 @2.6GHz	X		X	16core + 16ht
rocdev1	Pentium 4 @2.8GHz	X			RHEL5 system for compiling ROLs for DAQ
hdguest0-3	i5-3470 @3.2GHz	X (outside network)			Guest consoles in cubicles (outside network)

New farm nodes

OLD GLUON FARM NODE

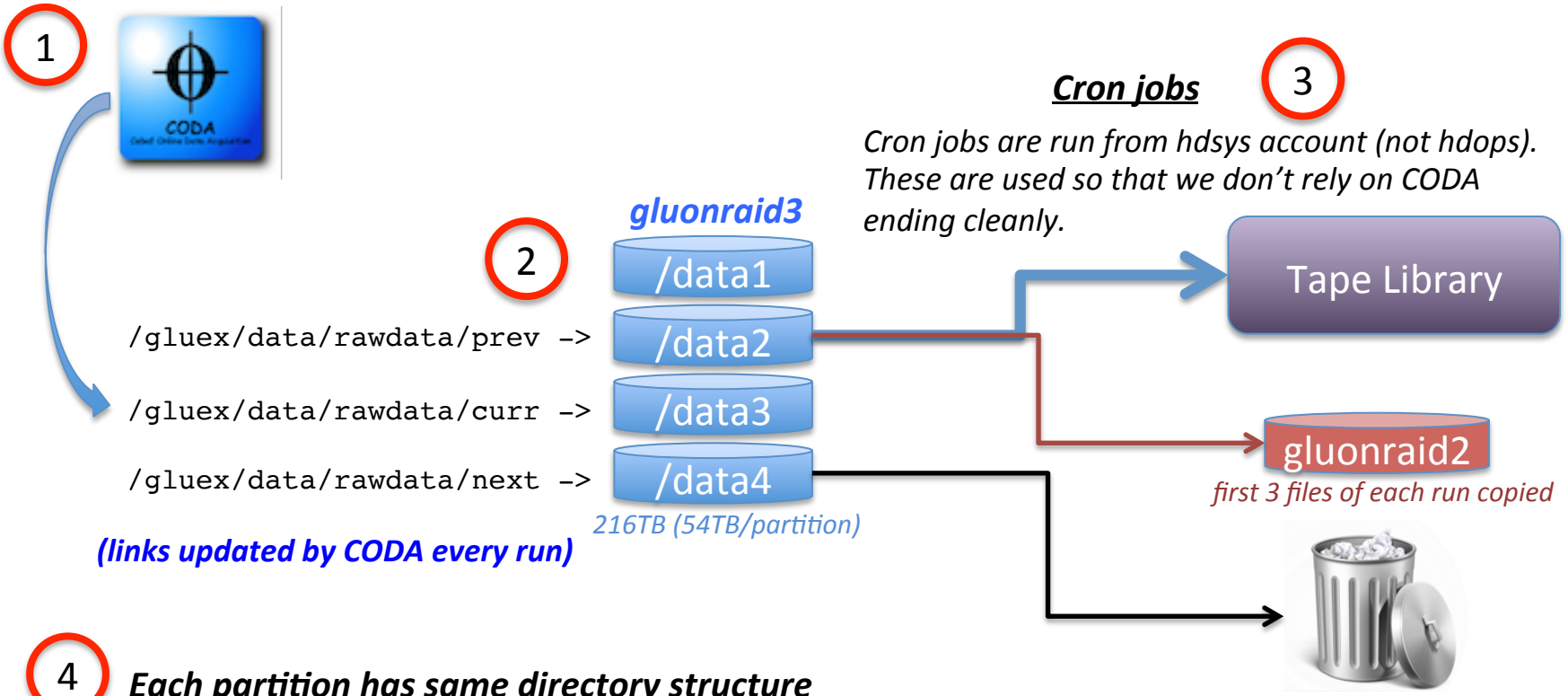


NEW GLUON FARM NODE



- 8 new Broadwell based farm nodes installed
- Previous farm consisted of 12 Ivy Bridge nodes
- Farm now has 2.5 times as much CPU as Spring

Raw Data Flow



4 ***Each partition has same directory structure***

`/…/active`	Data written to "active"
`/…/volatile`	Data moved to "volatile" once partition is inactive
`/…/staging`	Data hard linked in "staging" for copy to tape

Disk mapping + auto-deletion 5

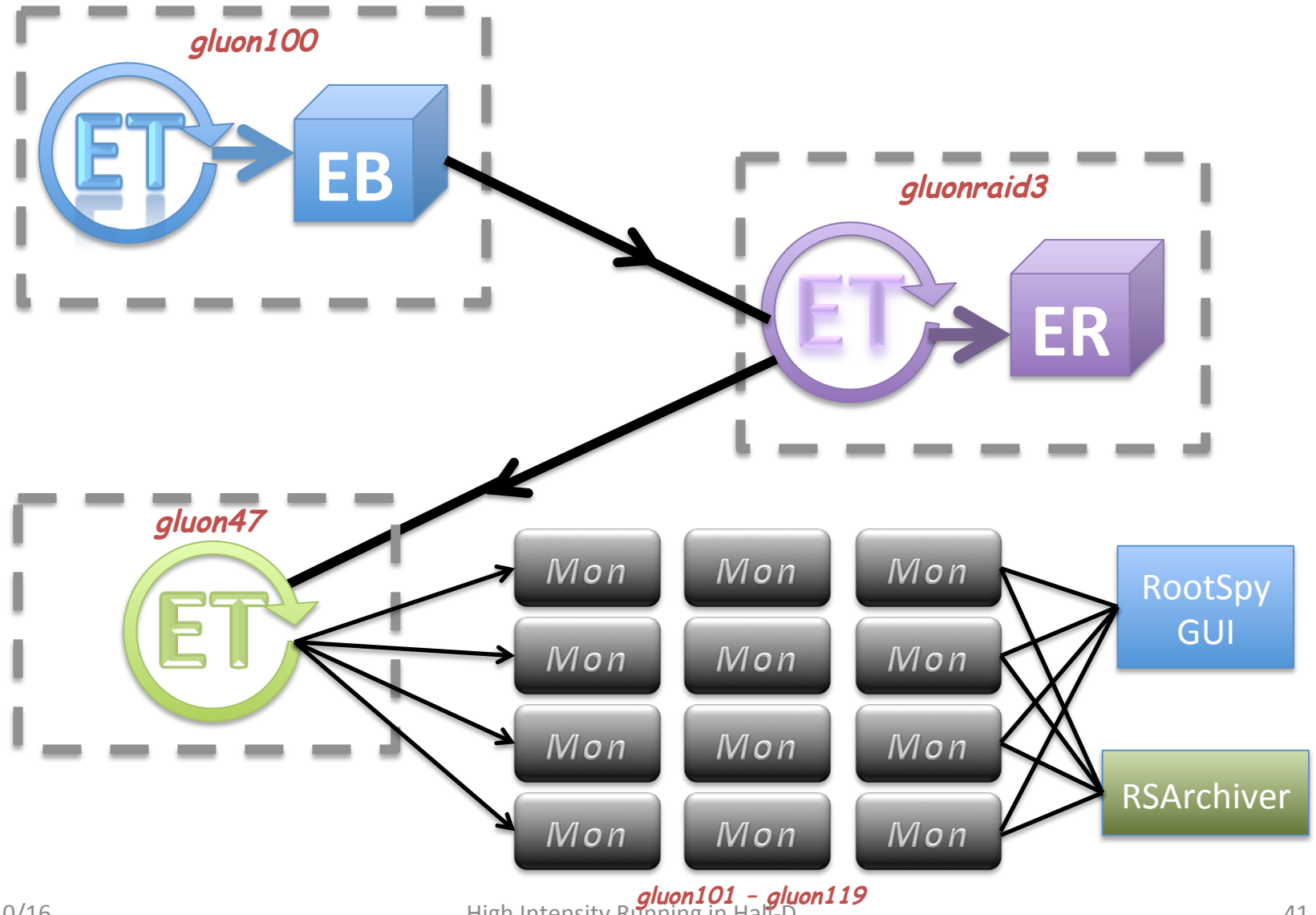
Old scheme:

- *Entire RAID disk mapped via cron job*
- *Files deleted "by hand" just before switching disks*

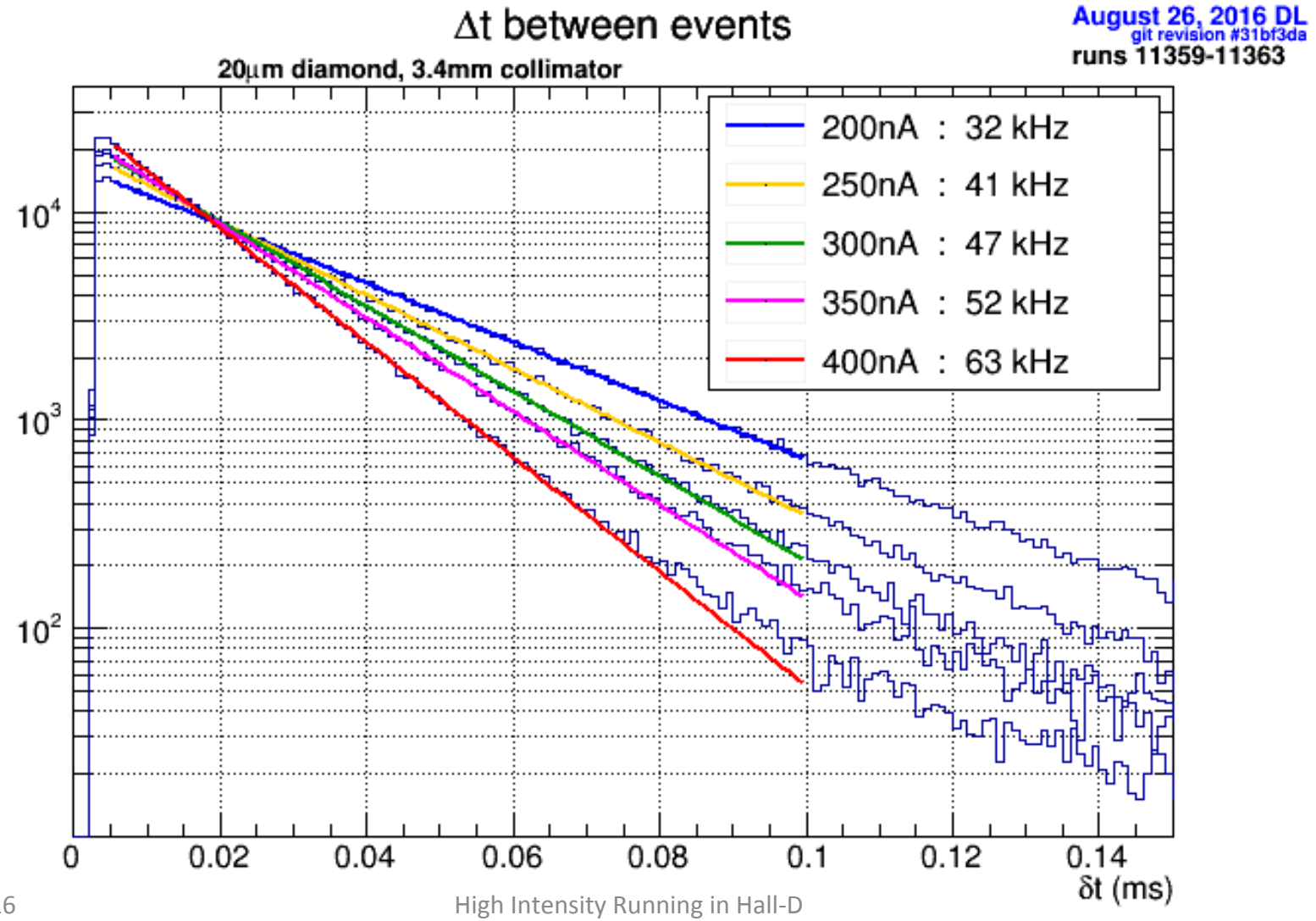
New scheme:

- *Map only volatile directory*
- *Map only when data moved to volatile (via cron)*
- *Auto-delete files from volatile to ensure 16.4TB is free*

Hall-D Online Monitoring Architecture

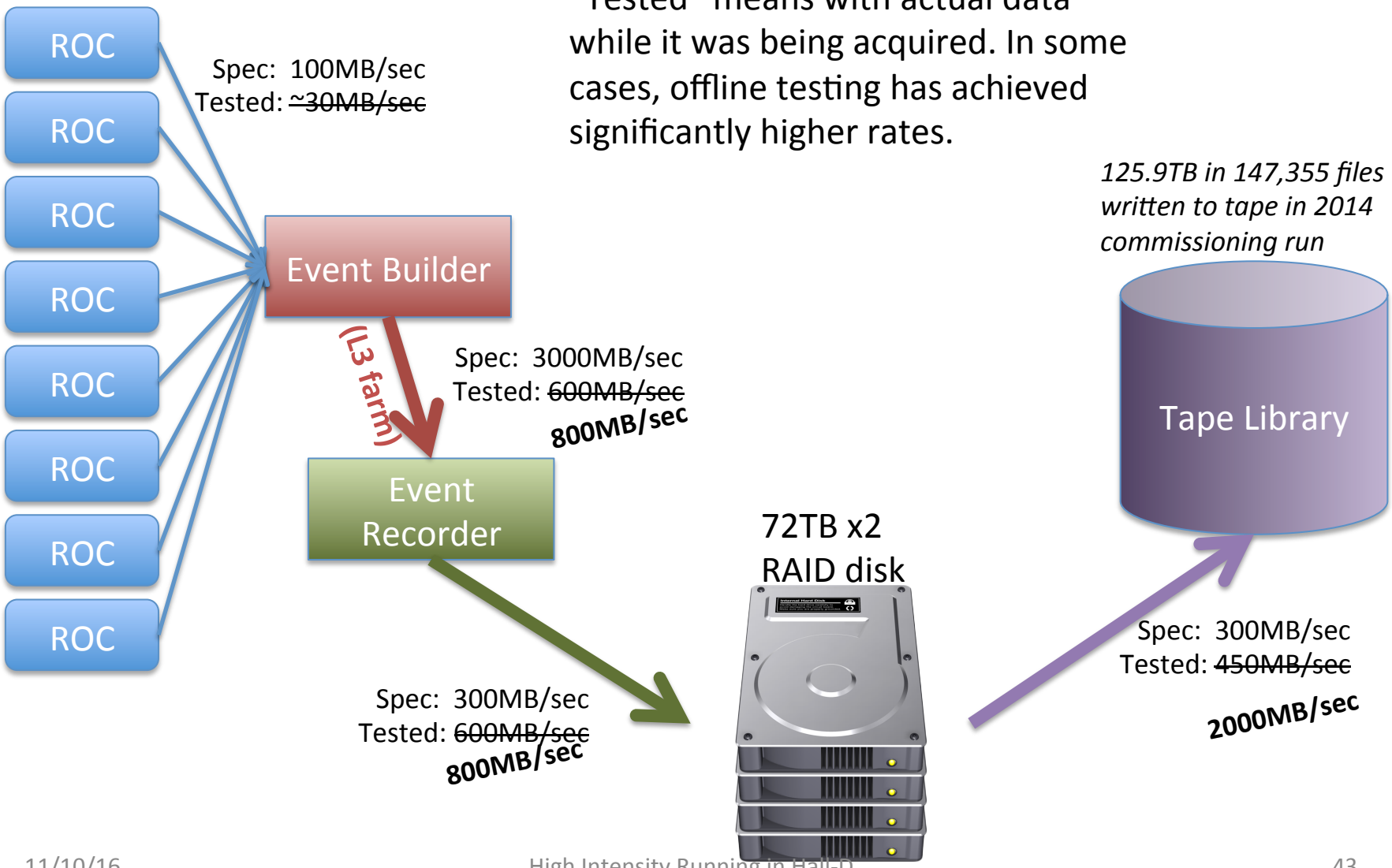


- Working on extracting L1 trigger rate from time between events
- Dropping events based on stricter L1 trigger thresholds would allow estimate of L1 trigger rate with these existing data files



Data Rates

"Tested" means with actual data while it was being acquired. In some cases, offline testing has achieved significantly higher rates.



Online Storage Capacity

- Two RAID disks with 72TB each of usable space
  - Maintain some portion of recent data
  - ~100TB effective space total for new data
- Need 72hr buffer in case of issue with link to tape library
- 100TB ÷ 800MB/s = 35hr
- Need additional 100TB of RAID
  - Will purchase this summer