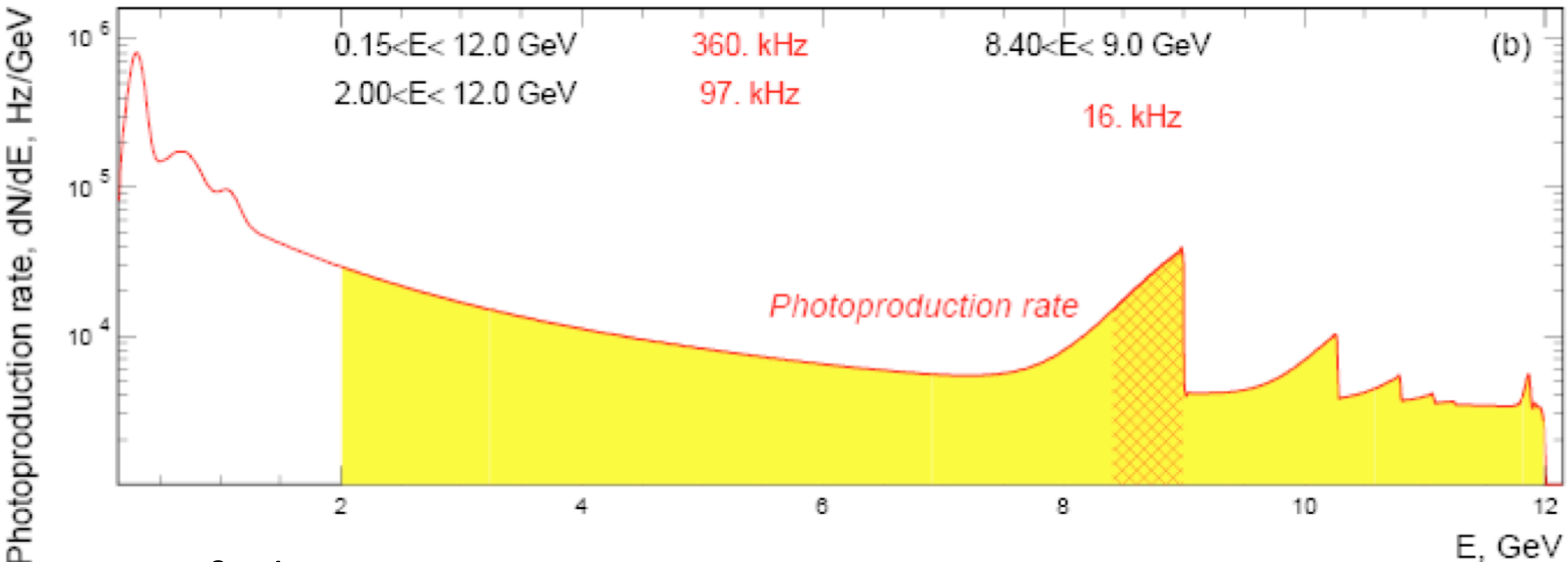
Hall-D L3 trigger status

David Lawrence JLab

July 22, 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.



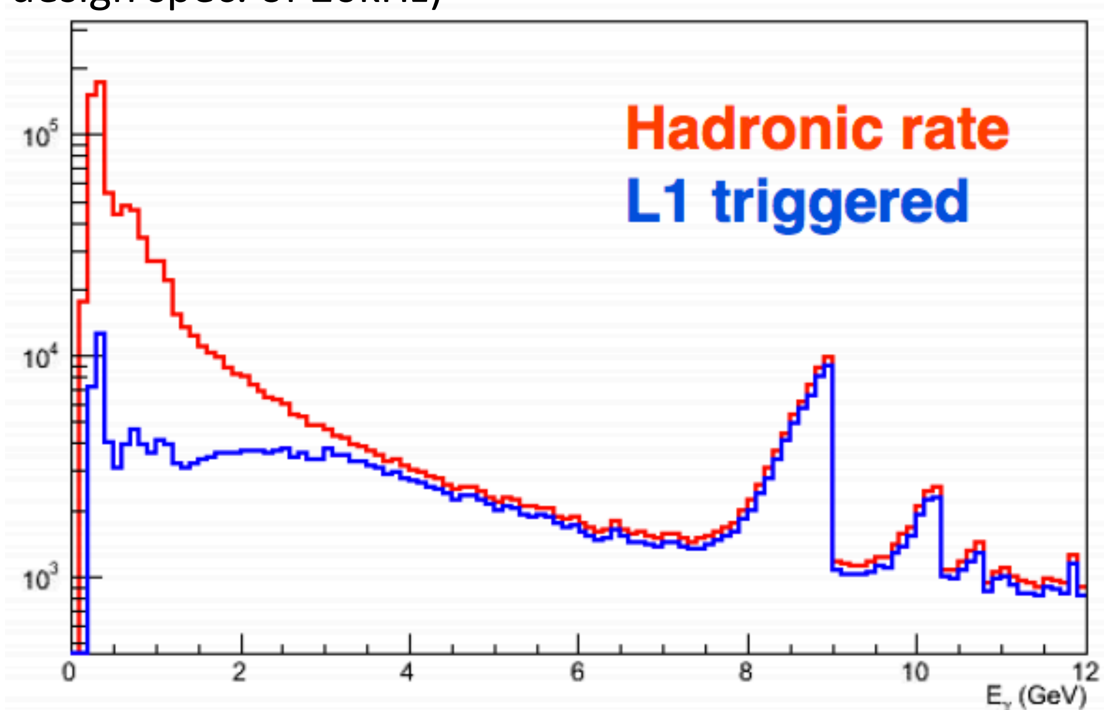
- 10^8 γ/s on LH_2 target -> ~400kHz hadronic rate
- L1 trigger goal is to cut away ~50% leaving 200kHz
- L3 trigger goal is to reduce by ~90% leaving 20kHz ***actual: ~75%***
- Early simulation suggested ~15kB/event ***actual: 14kB + 0.05kB/nA****
  - 15kB/event @ 200 kHz = 3000 MB/s (front end)
  - L3 reduction by factor of 10 = 300MB/s to RAID disk

**40μm diamond, 5mm collimator*

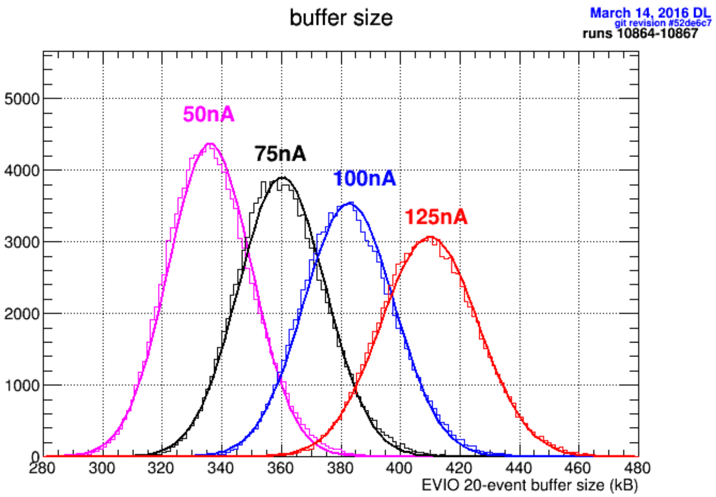
L1 Trigger Status

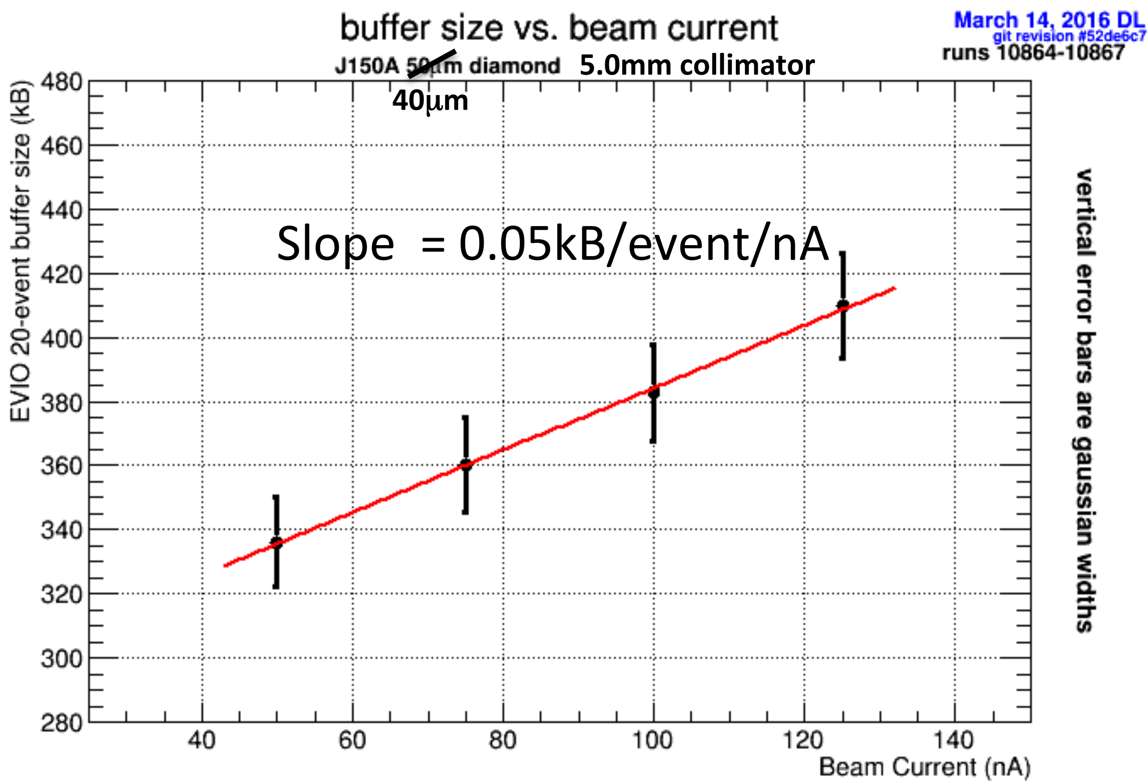
- L1 trigger (primarily) energy in calorimeters (FCAL and BCAL)
  - Cuts out
    - Events induced by low energy photons
    - EM events from rescattered pairs near beamline
  - "Low luminosity" rate of 10^7 γ/s on target in coherent peak (8.4-9GeV)
    - achieved in Spring 2016 run
    - 30kHz event rate (vs. old design spec. of 20kHz)
  - L1 well Optimized
    (little room for improvement)

- *Future (Fall 2018) requires 5x higher luminosity or $1x10^7$ γ/s*



Event Size vs. Beam Current





Event Size: ~19kB

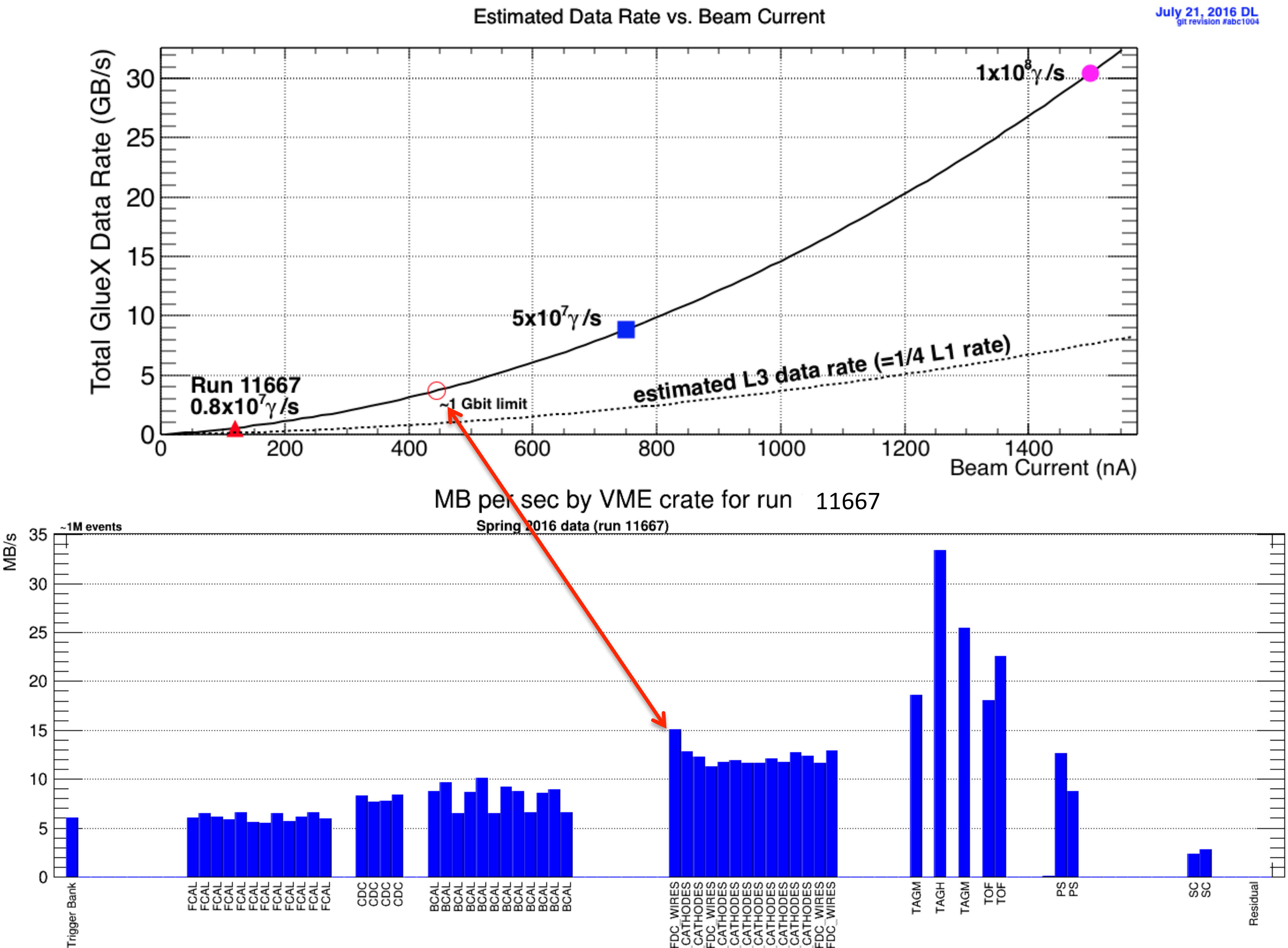
40μm diamond
5mm collimator
120nA = 0.8x10⁷ γ/s
750nA = 5x10⁷ γ/s

extrapolate to I_{beam}= 0 → 14.25kB/event
(size of clean event with no accidentals)

Accidental data fraction (by volume):

$$\frac{(0.05\text{kB/nA})(I_{beam}\ \text{nA})}{(0.05\text{kB/nA})(I_{beam}\ \text{nA}) + (14.25\text{kB})}$$

100nA: 26% of data is due to accidentals
200nA: 41% of data is due to accidentals
750nA: 72% of data is due to accidentals

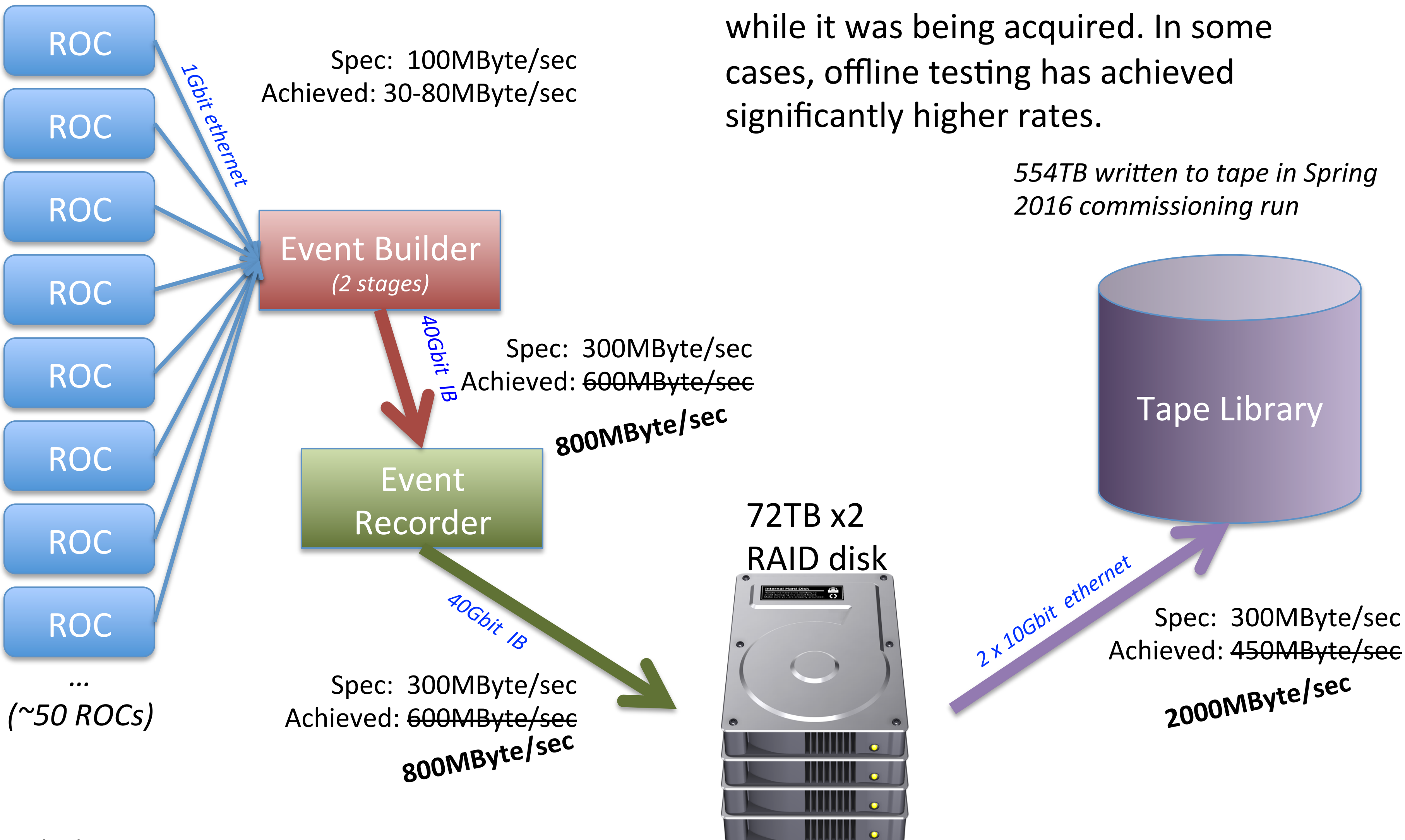

Estimated Data Rate vs. Beam Current
July 21, 2016 DL
git revision #abc1004
Total GlueX Data Rate (GB/s)
Beam Current (nA)
1x10^8 γ/s
5x10^7 γ/s
Run 11667
0.8x10^7 γ/s
~1 Gbit limit
estimated L3 data rate (=1/4 L1 rate)
MB per sec by VME crate for run 11667
~1M events
Spring 2016 data (run 11667)
MB/s
Trigger Bank
FCAL
CDC
BCAL
FDC_WIRES
FDC_CATHODES
TAGM
TAGH
TOF
PS
SC
Residual

Data Rates

DAQ event rates
Fall 2014: 2kHz
Spring 2015: 3.5kHz
Spring 2016: 30kHz *<- low luminosity rate*

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

554TB written to tape in Spring 2016 commissioning run



Data Rates

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Fall 2014: 2kHz
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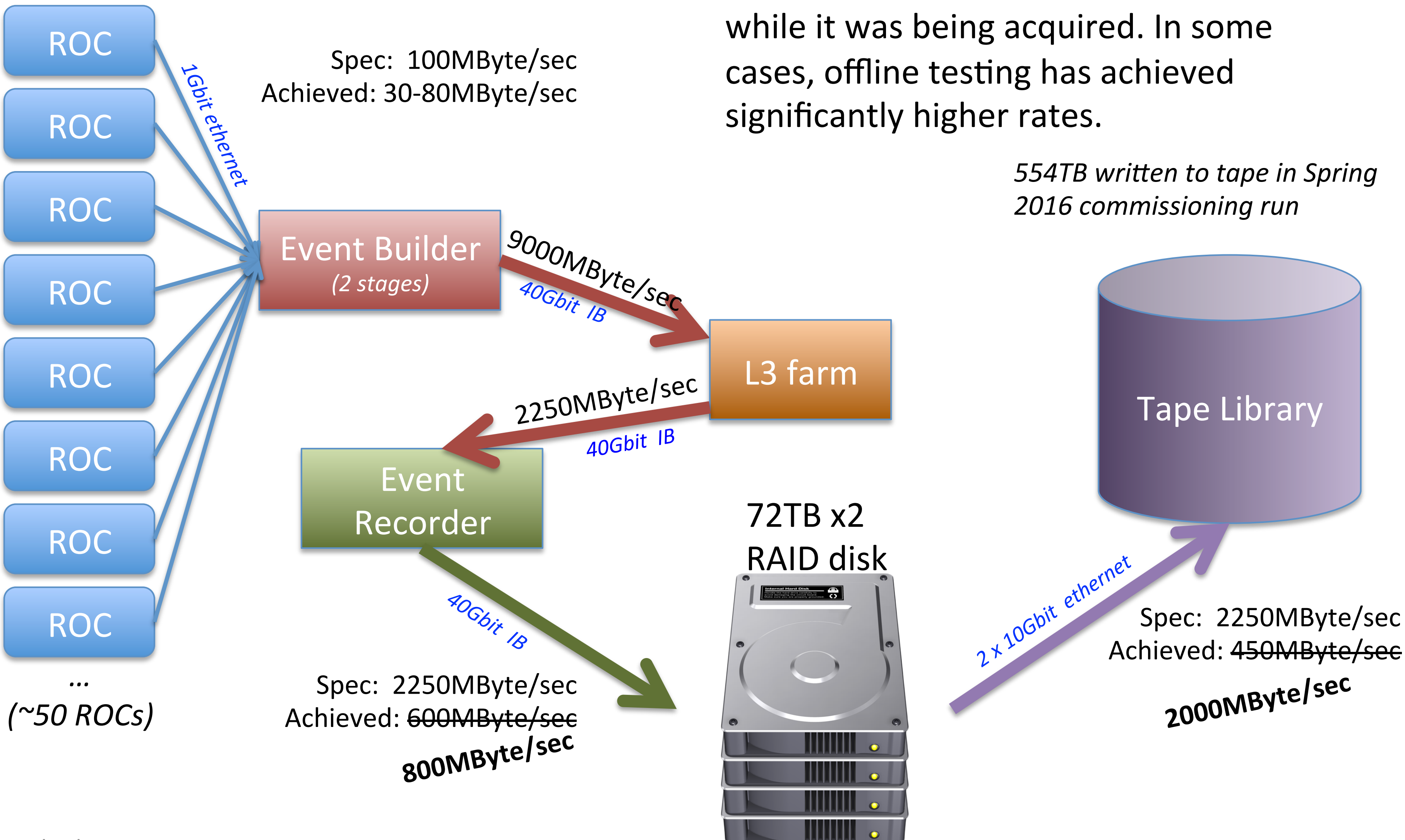
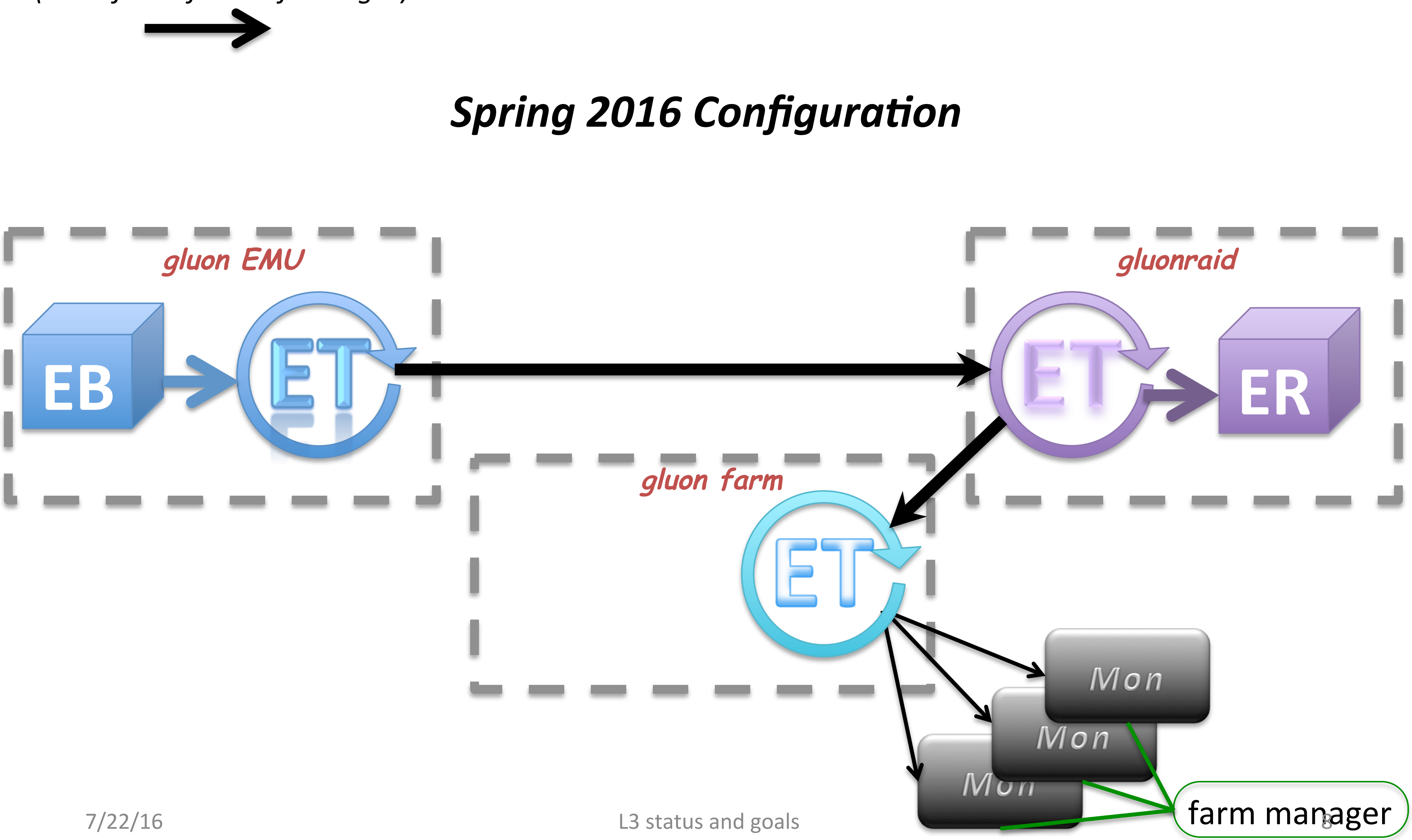


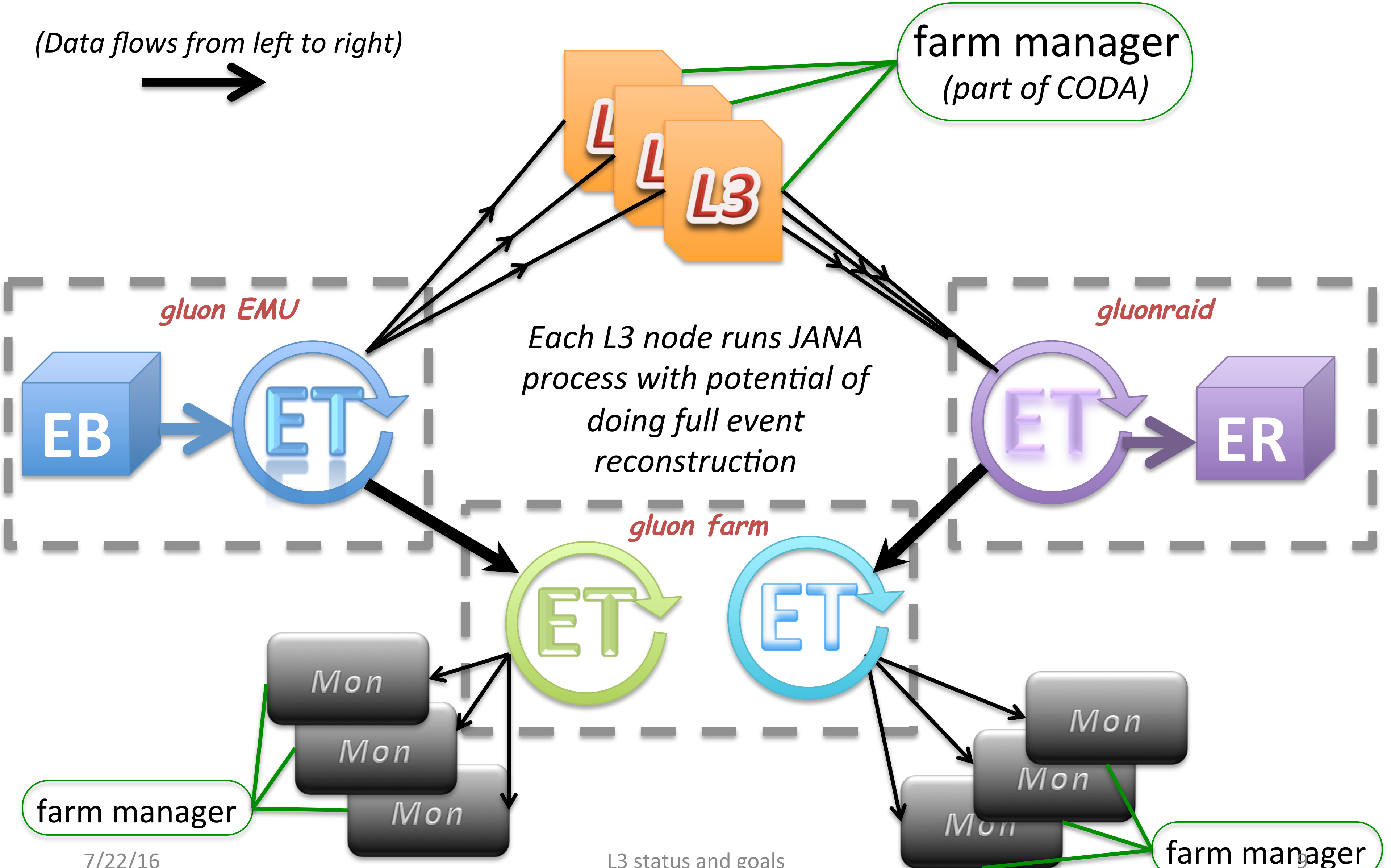
L3 and monitoring architecture

(Data flows from left to right)

Spring 2016 Configuration

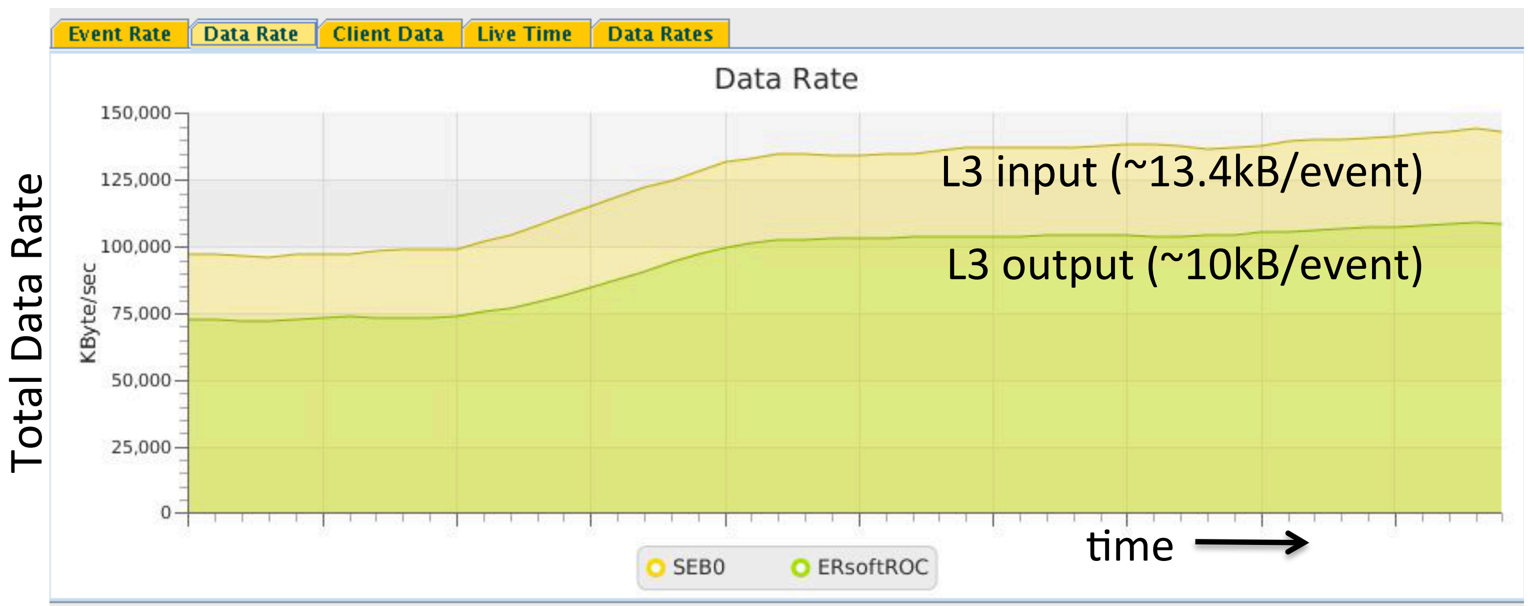


L3 and monitoring architecture



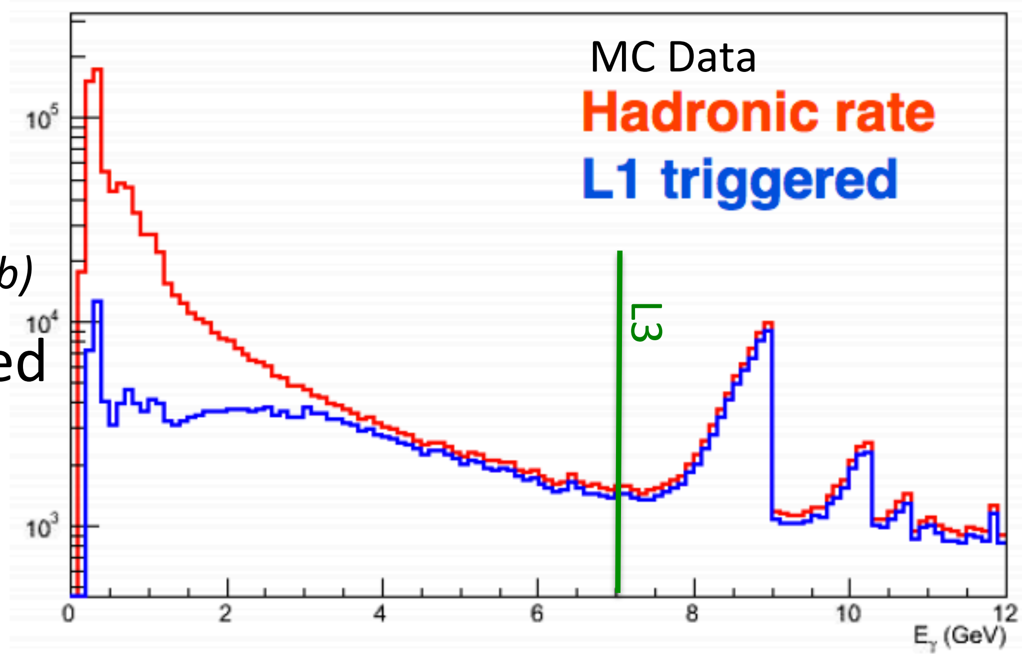
L3 running in pass-through with beam

- 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



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 Multivariate Analysis such as BDT or ANN to classify events
- 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

Slide from Cristiano F. presentation at July 8, 2016 L3 trigger meeting

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

input file: hd_rawdata_010913_060.phys_skim.evio

DATA

events	ALGORITHM	INPUT OBJECT	RECO TIME [s]	RECO TIME/event [ms]
10000	nominal reco	DNeutralShower	4.410	**0.028**
	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

MC

events	ALGORITHM	INPUT OBJECT	RECO TIME [s]	RECO TIME/event [ms]
10000	nominal reco	DNeutralShower	5.730	**0.036**
	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

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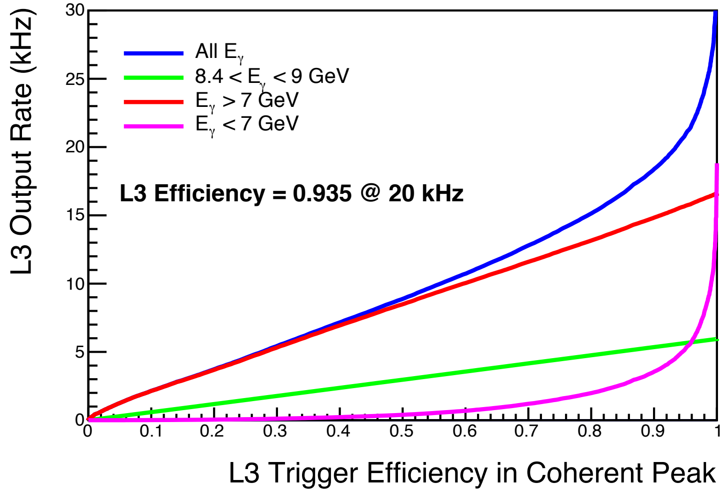
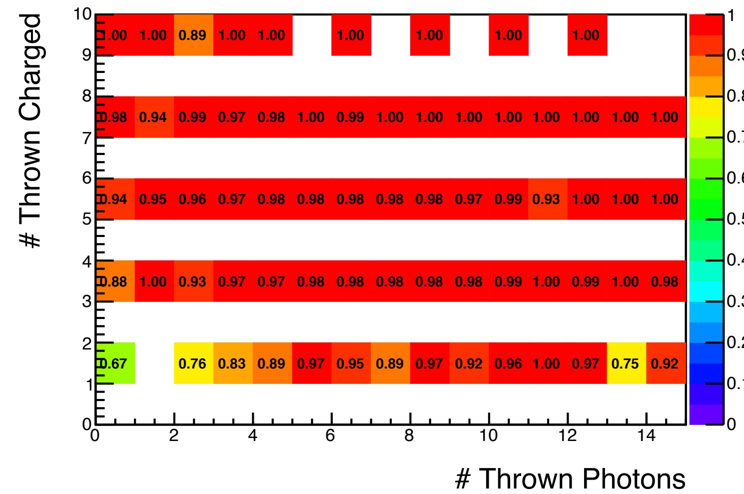
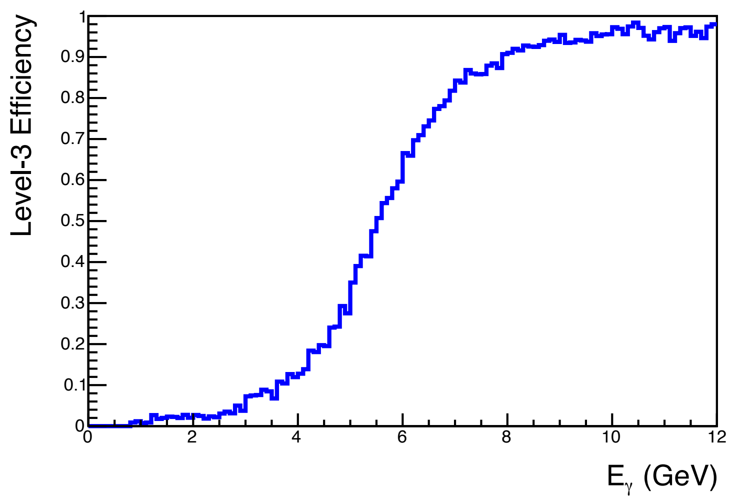
Slide from Justin S. presentation at July 8, 2016 L3 trigger meeting

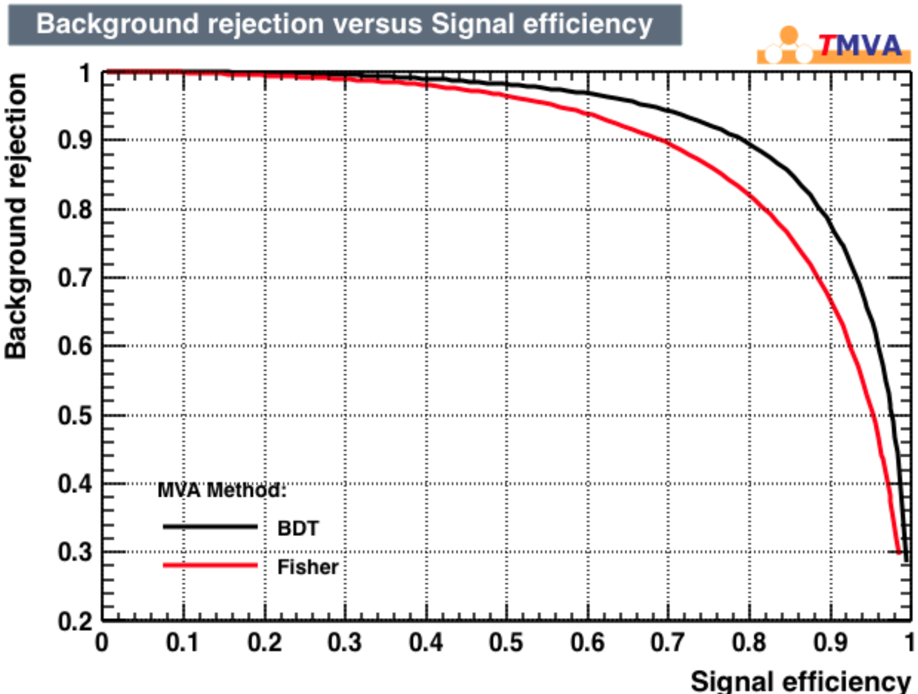
Level-3 BDT Evaluation

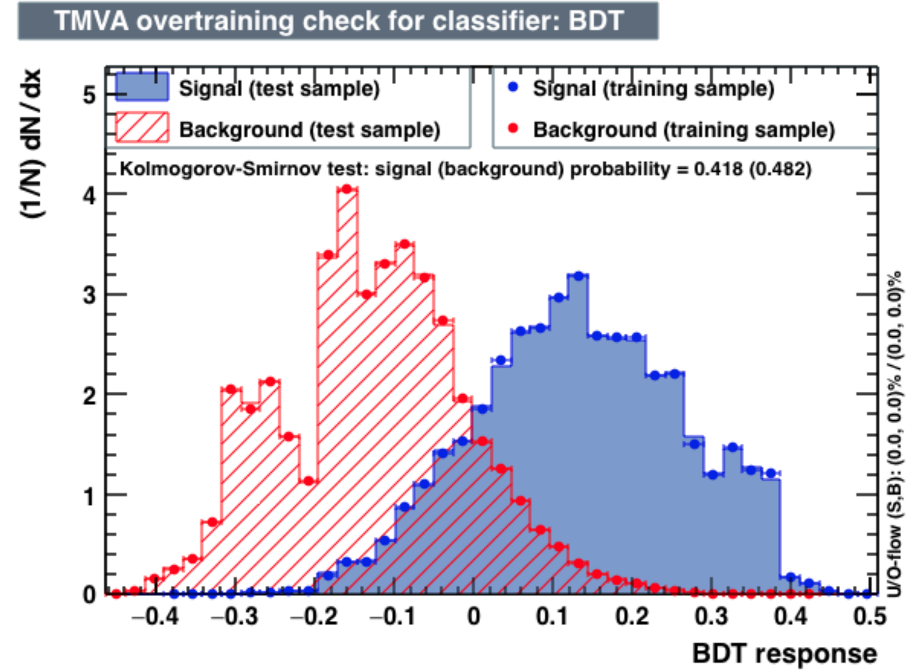






- Machinery resurrected for training and evaluating BDT for simulation
- Similar performance as seen in studies ~2 years ago
- Lower efficiency for low multiplicity final states






```
--- 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*

Estimated number of L3 nodes

- From Spring 2016 running: ~30kHz/0.8x10^7 γ/s
- For 5x10^7 γ/s: ~190kHz
- 2013 Ivy Bridge nodes
  - 2.5-13kHz parsing only
  - 4kHz parsing+neutrals recon
  - 2kHz final algorithm *(rough estimate)*
- Newer nodes assume x2 faster
  - 4kHz/node
- Total number of nodes required:
  - 190kHz/4kHz = **48**

Schedule

- Continue L3 development, testing infrastructure and MVA efficiency through Fall
- Integrate testing schedule into Fall 2016 run
- If confident, take portion of Spring 2017 data in pass-through mode
  - Events on tape will be reconstituted single events
  - Event tagging may be used if fast algorithm available
- Full L3 deployment Fall 2018

Issues Requiring Attention

- fADC125 high rate performance
  - Busy signals *(currently being tested in Hall-D)*
- Individual VME crate saturates 1Gbit link
  - 10Gbit ethernet cards in ROCS
  - Split crates *(either backplanes or add additional crates)*
  - Parallel module readout *(VXS, or new fADC125 daughters)*
- 50 ROCs pushing 9GB/s through full CODA system
  - Minimize single crate data size to allow high luminosity testing
  - Tuning IB network or splitting streams

Backup Slides

Detectors At High Rate

- FDC aging effects for wires closest to beamline
- FCAL innermost blocks radiation damage
  - Curing
  - Replace with rad-hard insert

- Potential concern for the CDC and FDC is the aging of the wires: high currents in the chambers which, especially in presence of organic contamination, can result in formation of deposits on the wire surface (like polymers) and manifest as a decrease of the gas gain.

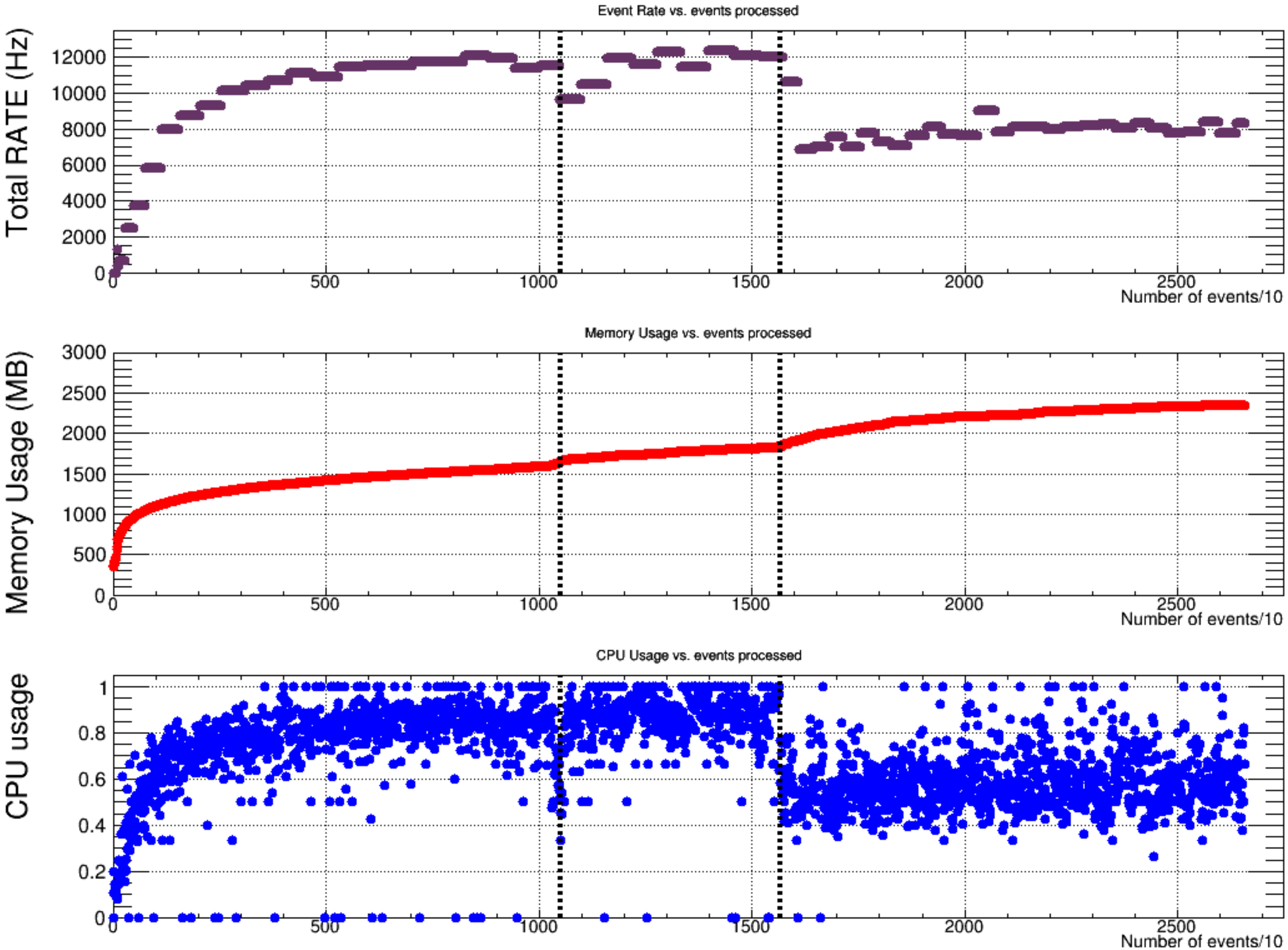
- The relevant quantity is the charge per unit wire length. For the nominal low intensity during the commissioning/engineering running we had in the inner FDC HV sector (20 wires) about 5 uA currents, which however is concentrated to the area closest to the beam line, where we expect to have up to 1 uA/cm. In the CDC the currents on 24 inner straws was about 10 uA, but distributed evenly along each wire and between the 24 wires, corresponding to current densities of about 5 nA/cm.

- No wire aging effects at all have been observed in Ar/CO2 gas mixtures in studies with up to 1C/cm, which however corresponds to only ~12 beam-on-target days at low intensity. Up to now (??total charge/cm??) we have not seen any wire aging. Even wire aging is possible at higher intensities, it will be concentrated in a small area around the beam line.

- Conclusions: don't expect problems with the CDC; in FDC aging is possible but only in a small area around the beam.

- In order to mitigate potential aging effects due to radiation we do add alcohol to the gas. This is proven to stop the progress of aging if already present and inhibit aging from happening in the first place. As an example HallC operated their wire chambers for more than a decade now using alcohol in the gas mix and to my knowledge no aging has been observed. (This statement should be confirmed by Howard Fenker)

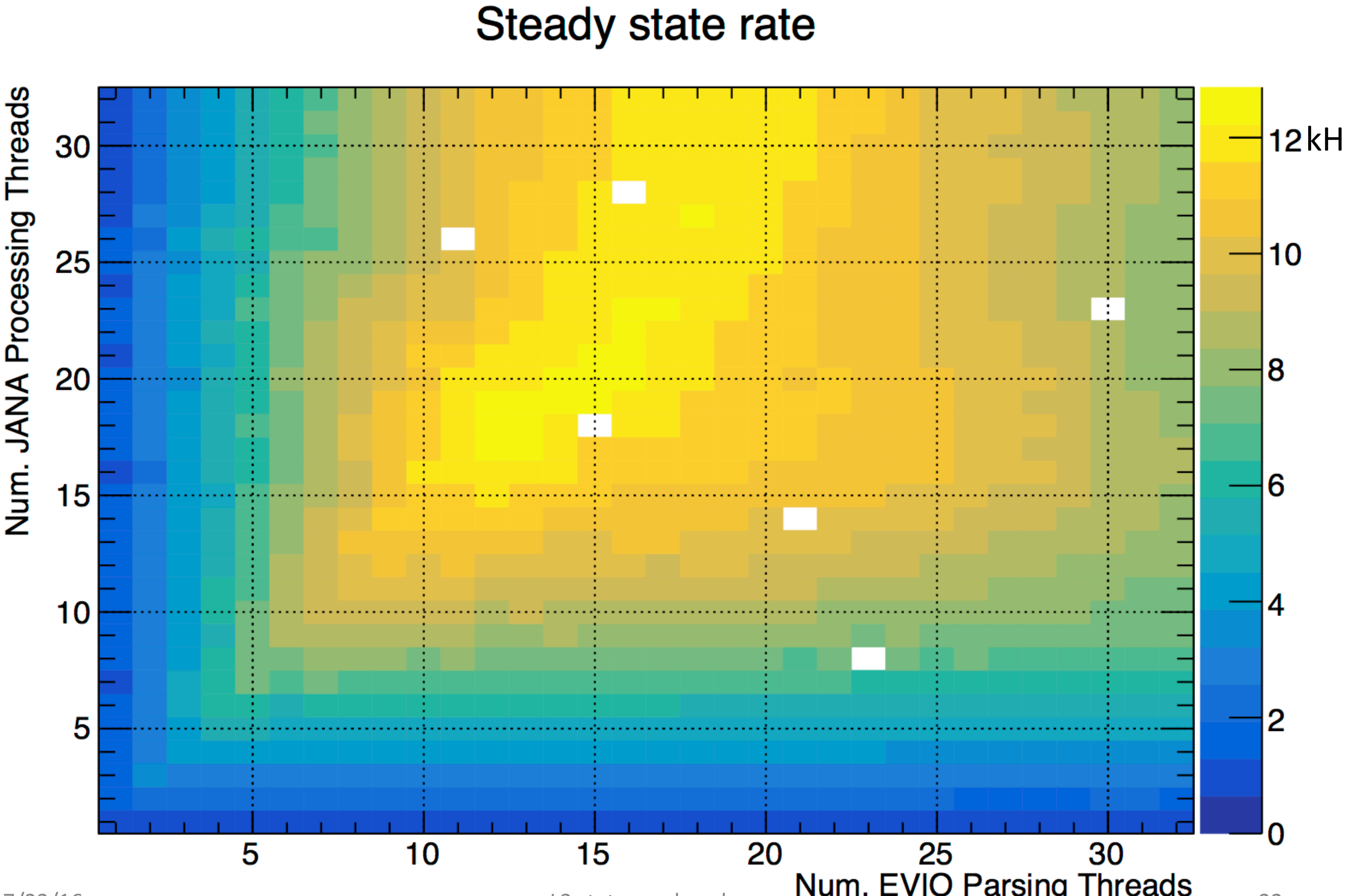
- One potential issue could be radiation damage to the FCAL lead glasses over the prolonged period of high-luminosity running.

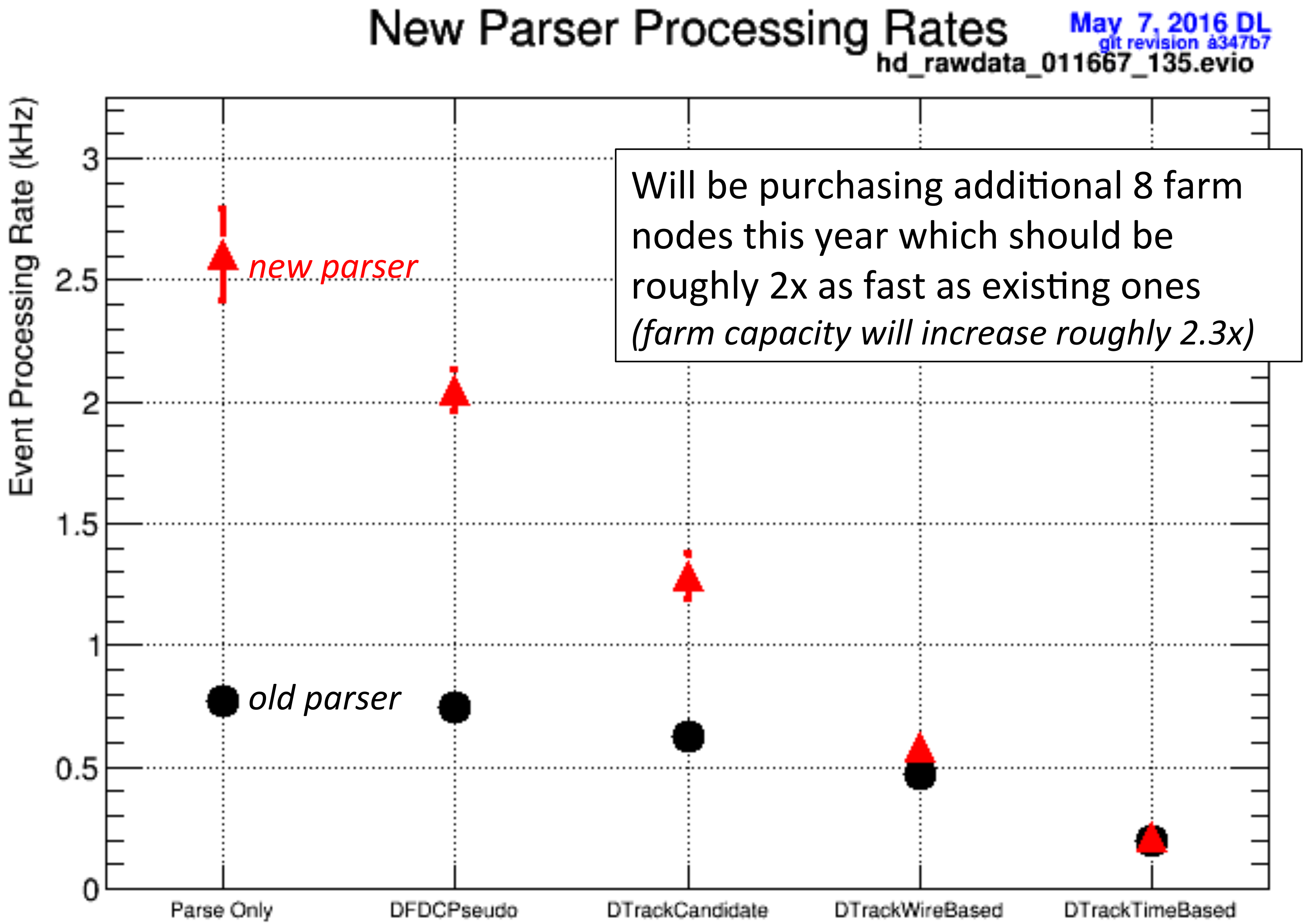


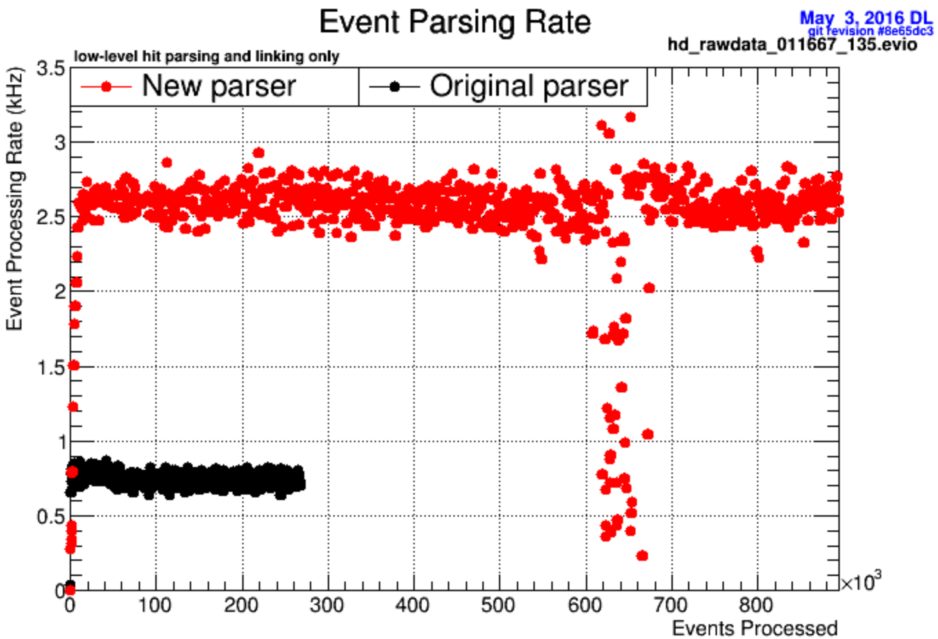
Event Rate vs. events processed
Total RATE (Hz)
0
2000
4000
6000
8000
10000
12000
500
1000
1500
2000
2500
Number of events/10
Memory Usage vs. events processed
Memory Usage (MB)
0
500
1000
1500
2000
2500
3000
Number of events/10
CPU Usage vs. events processed
CPU usage
0
0.2
0.4
0.6
0.8
1
Number of events/10

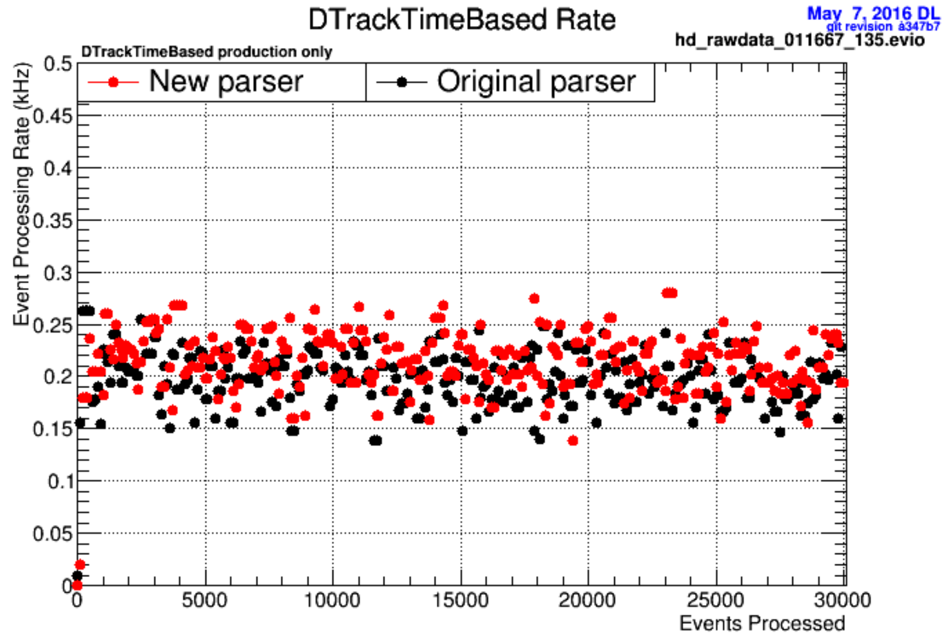
Parsing only

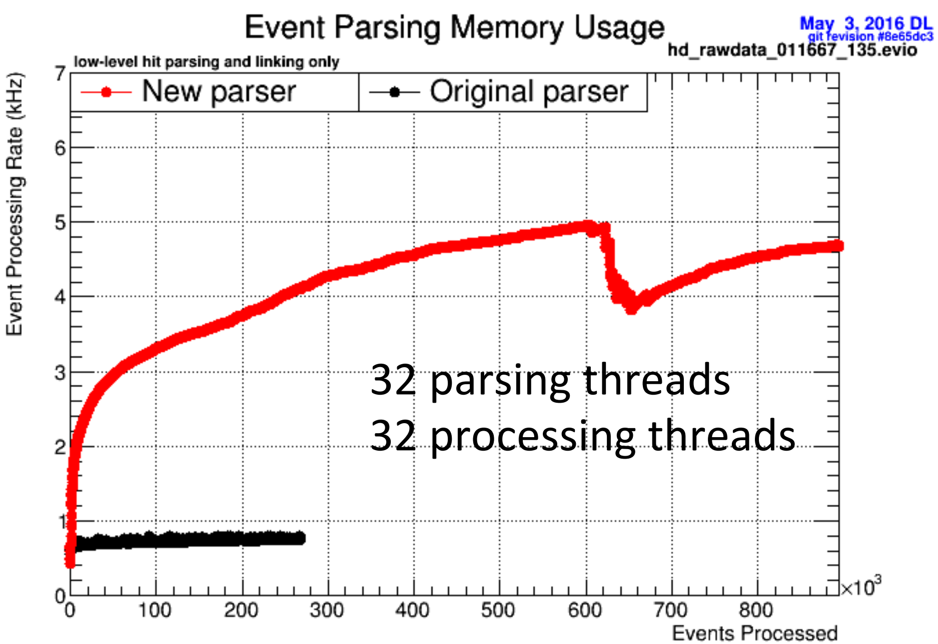
(no linking, no reconstruction)

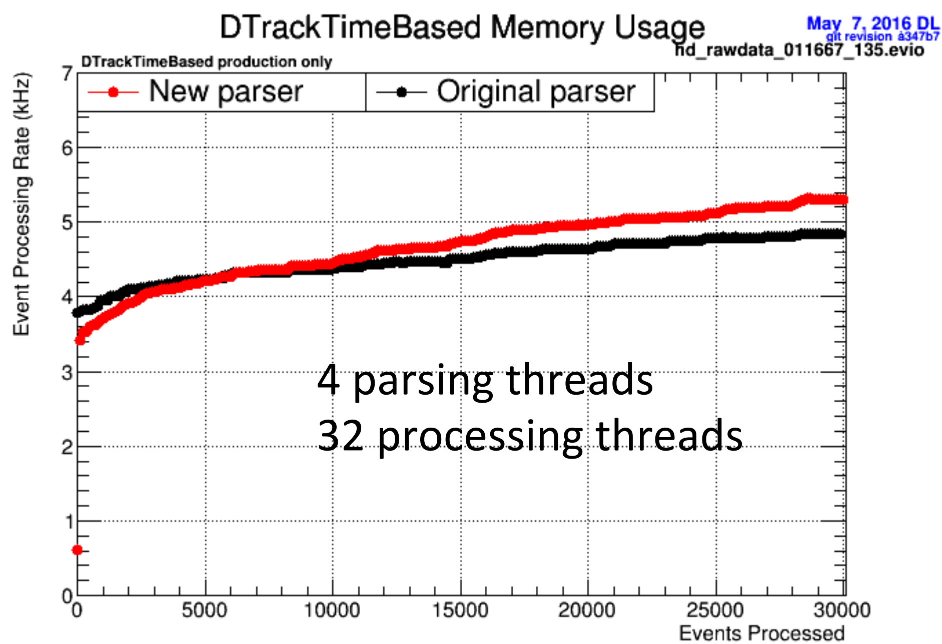


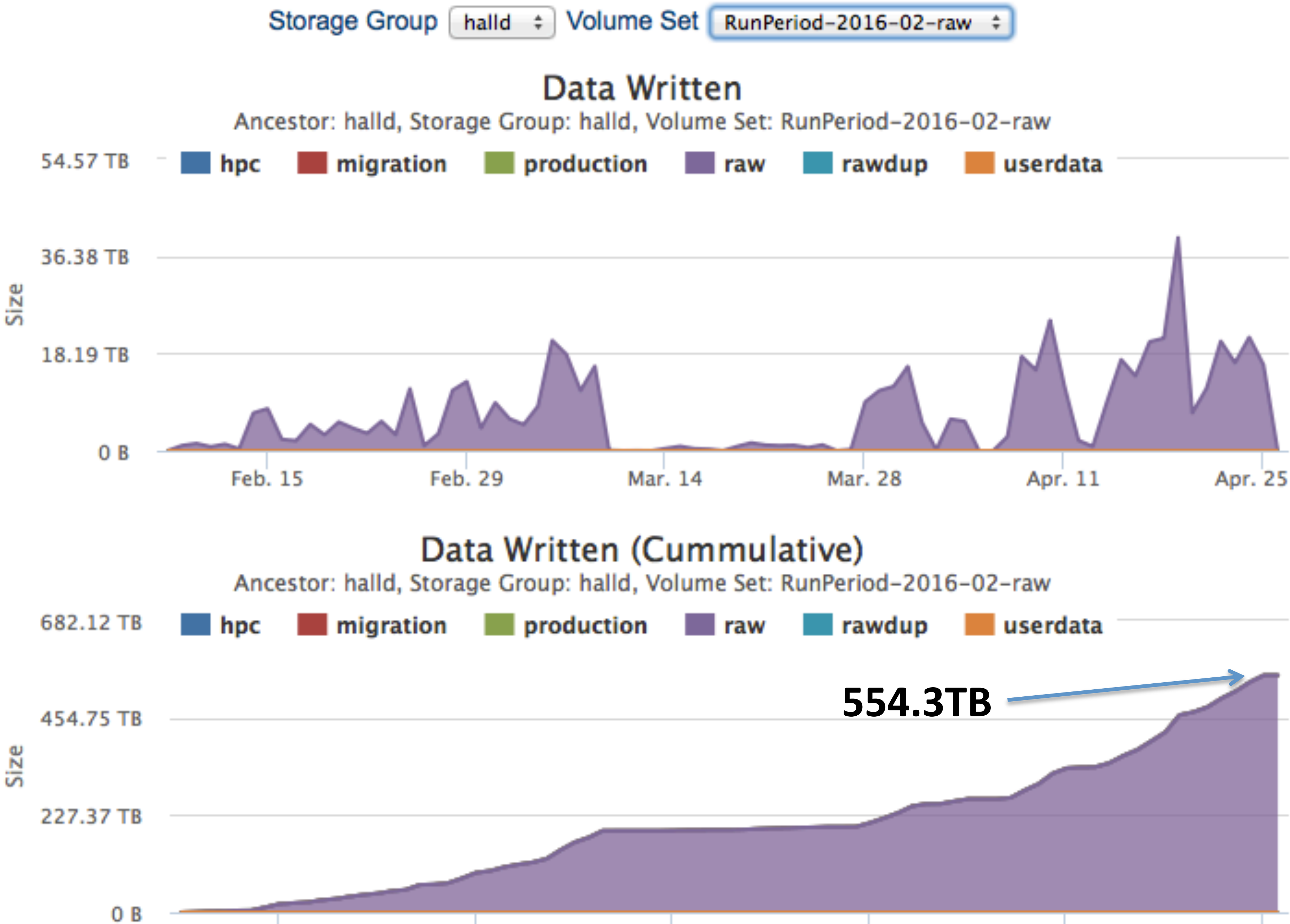

New Parser Processing Rates
May 7, 2016 DL
git revision a347b7
hd_rawdata_011667_135.evio
Event Processing Rate (kHz)
0
0.5
1
1.5
2
2.5
3
new parser
old parser
Parse Only
DFDCPseudo
DTrackCandidate
DTrackWireBased
DTrackTimeBased
Will be purchasing additional 8 farm nodes this year which should be roughly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


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
×10^3


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
×10^3
32 parsing threads
32 processing threads

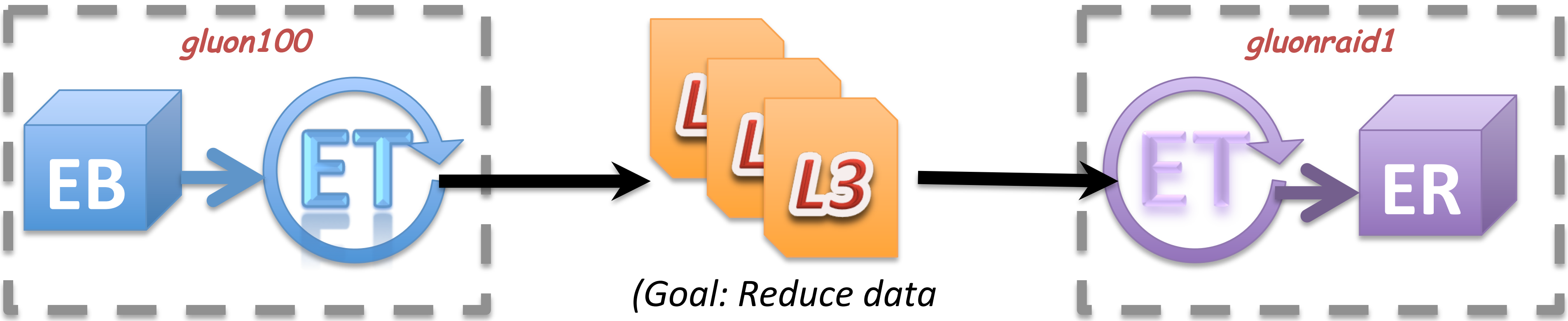

DTrackTimeBased Memory Usage
May 7, 2016 DL
git revision a347b7
hd_rawdata_011667_135.evio
DTrackTimeBased production only
New parser
Original parser
Event Processing Rate (kHz)
Events Processed
4 parsing threads
32 processing threads


Storage Group
halld
Volume Set
RunPeriod-2016-02-raw
Data Written
Ancestor: halld, Storage Group: halld, Volume Set: RunPeriod-2016-02-raw
hpc
migration
production
raw
rawdup
userdata
54.57 TB
36.38 TB
18.19 TB
0 B
Size
Feb. 15
Feb. 29
Mar. 14
Mar. 28
Apr. 11
Apr. 25
Data Written (Cummulative)
Ancestor: halld, Storage Group: halld, Volume Set: RunPeriod-2016-02-raw
hpc
migration
production
raw
rawdup
userdata
682.12 TB
454.75 TB
227.37 TB
0 B
Size
554.3TB
Feb. 15
Feb. 29
Mar. 14
Mar. 28
Apr. 11
Apr. 25

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

L3 Testing

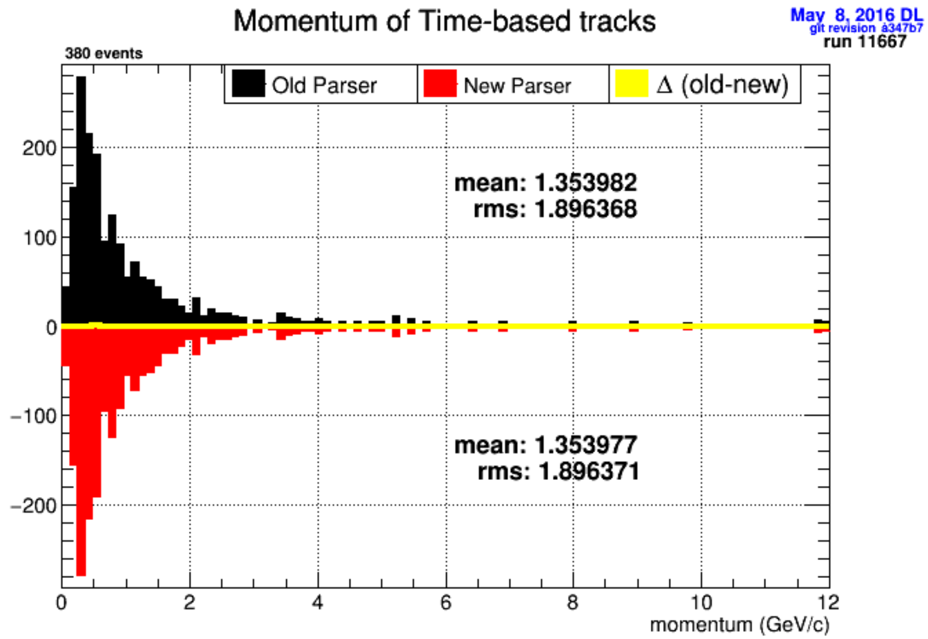


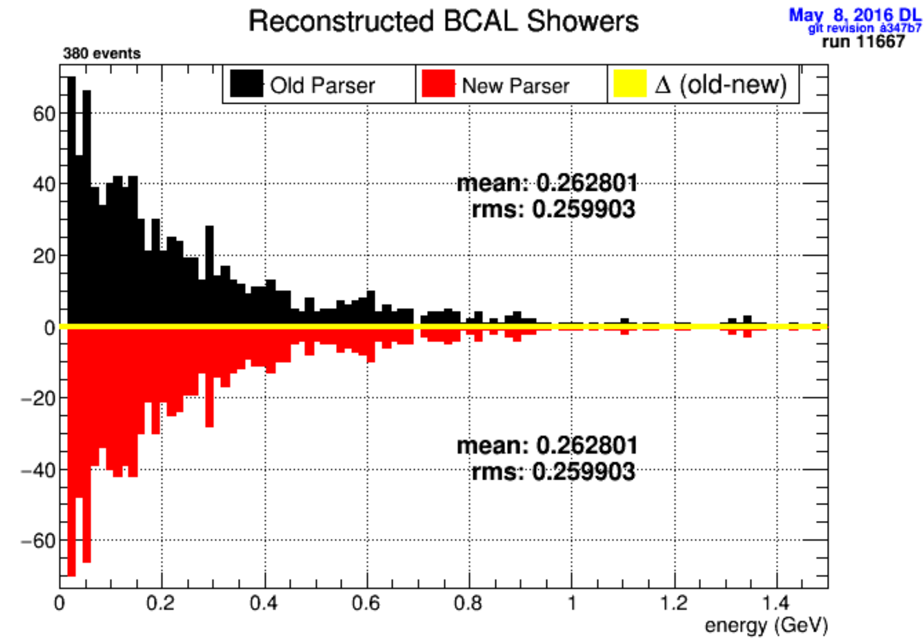
(Goal: Reduce data volume by factor of 10)

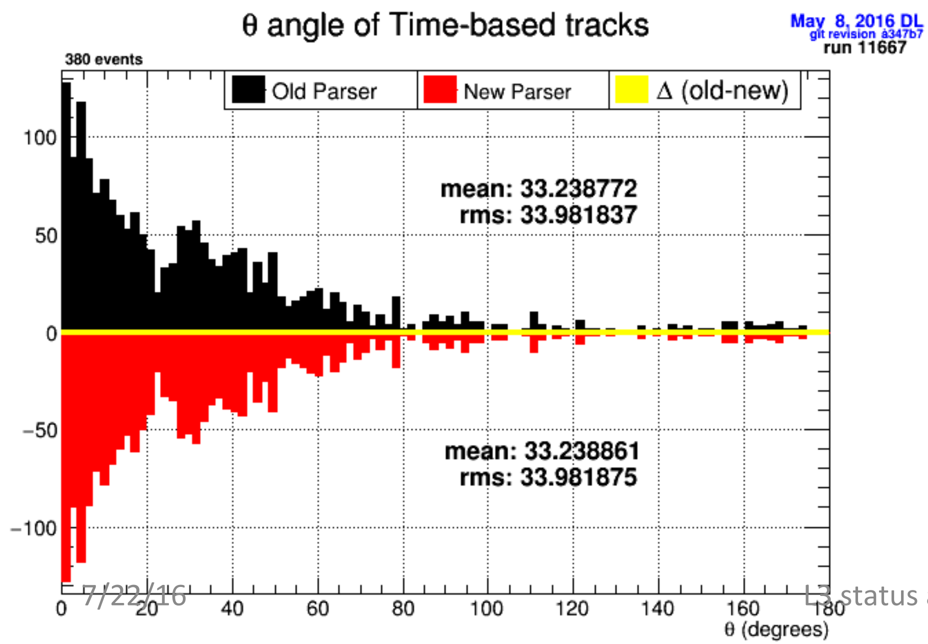
Spring 2016 L3 Testing

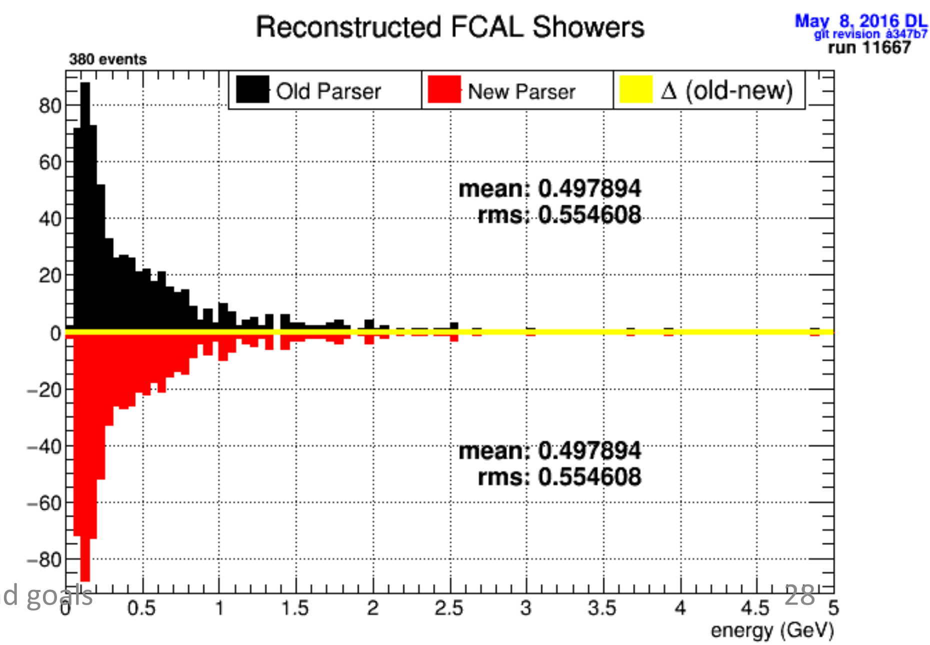
- Primarily infrastructure testing done
- Limited by 12 node farm to ~200MB/s parsing rate
- (~10kHz input rate)

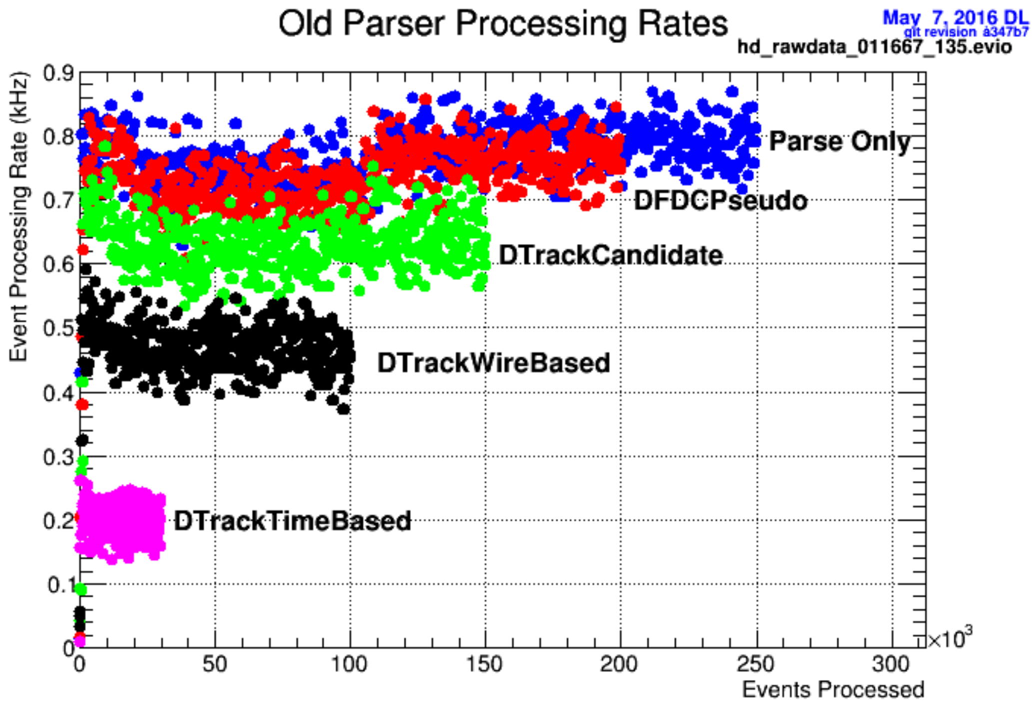
Reconstructed parameters for old and new parsers

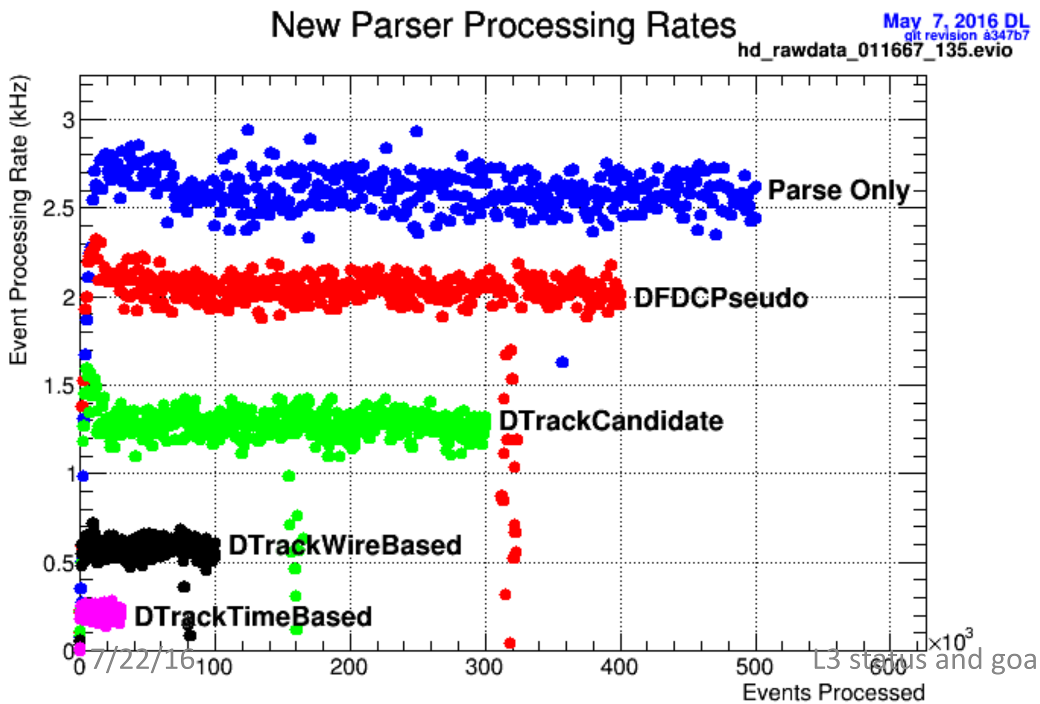


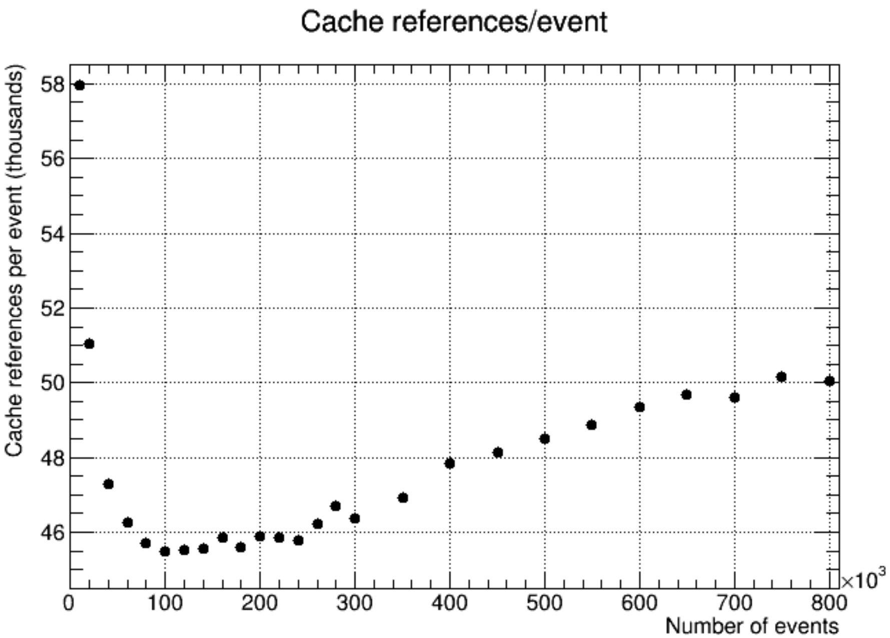


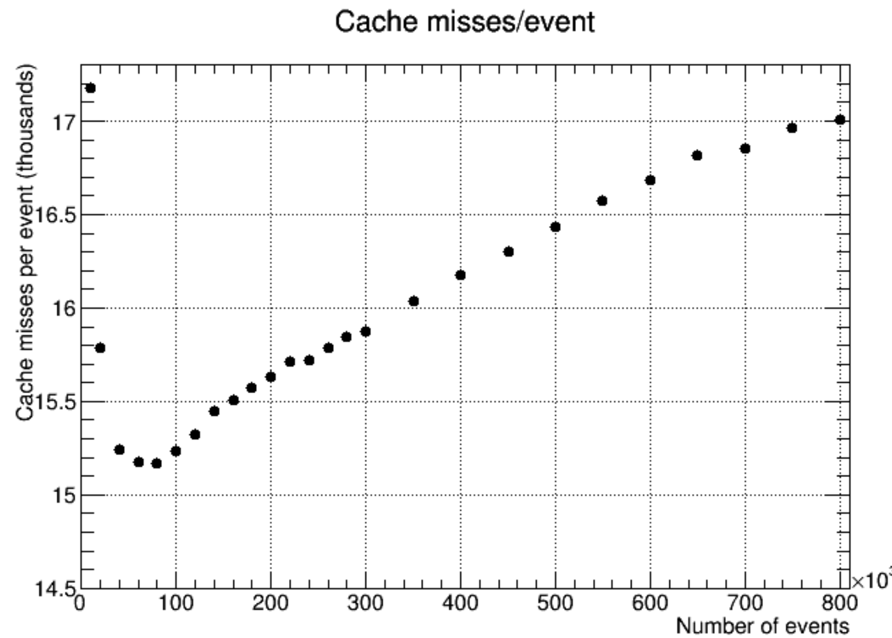


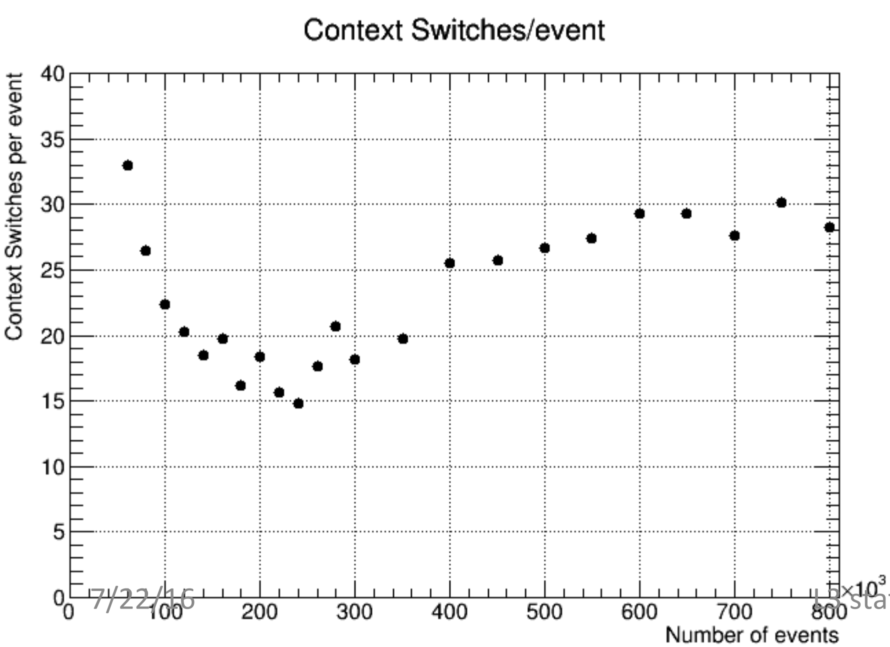


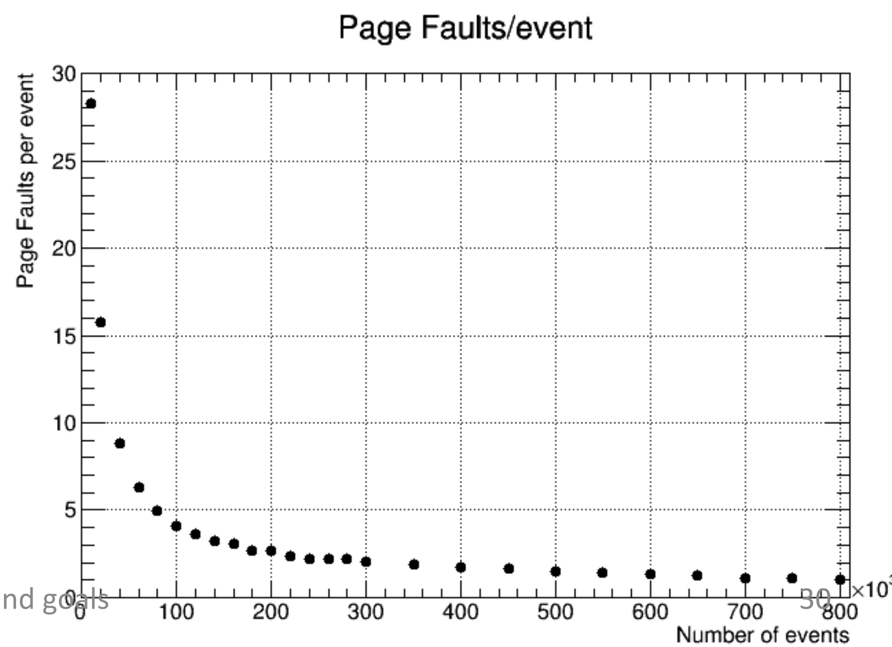

Old Parser Processing Rates
May 7, 2016 DL
git revision a347b7
hd_rawdata_011667_135.evio
Event Processing Rate (kHz)
Parse Only
DFDCPseudo
DTrackCandidate
DTrackWireBased
DTrackTimeBased
×10³
Events Processed


New Parser Processing Rates
May 7, 2016 DL
git revision a347b7
hd_rawdata_011667_135.evio
Event Processing Rate (kHz)
Parse Only
DFDCPseudo
DTrackCandidate
DTrackWireBased
DTrackTimeBased
×10³
Events Processed


Cache references/event
Cache references per event (thousands)
Number of events
×10^3


Cache misses/event
Cache misses per event (thousands)
Number of events
×10^3


Context Switches/event
Context Switches per event
Number of events
×10^3


Page Faults/event
Page Faults per event
Number of events
×10^3

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

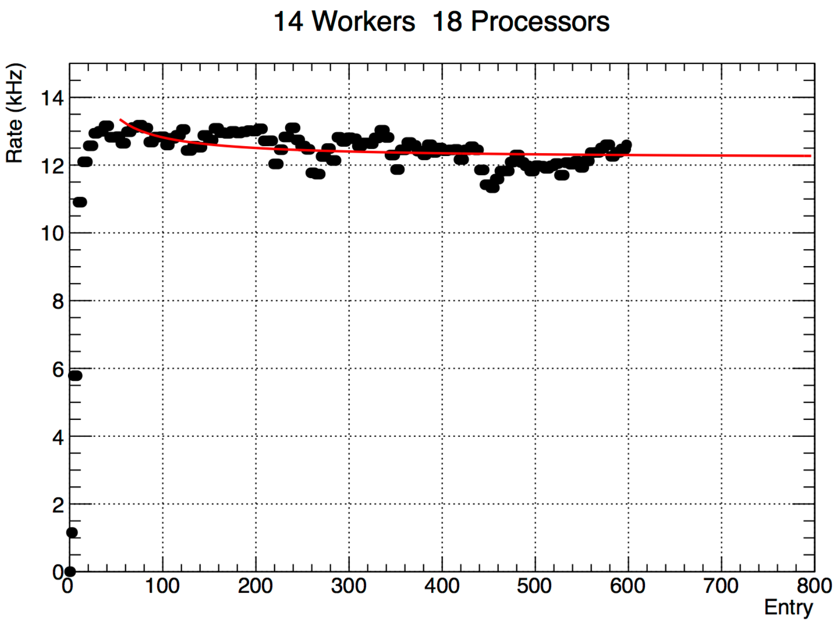
EVIO Parsing Time

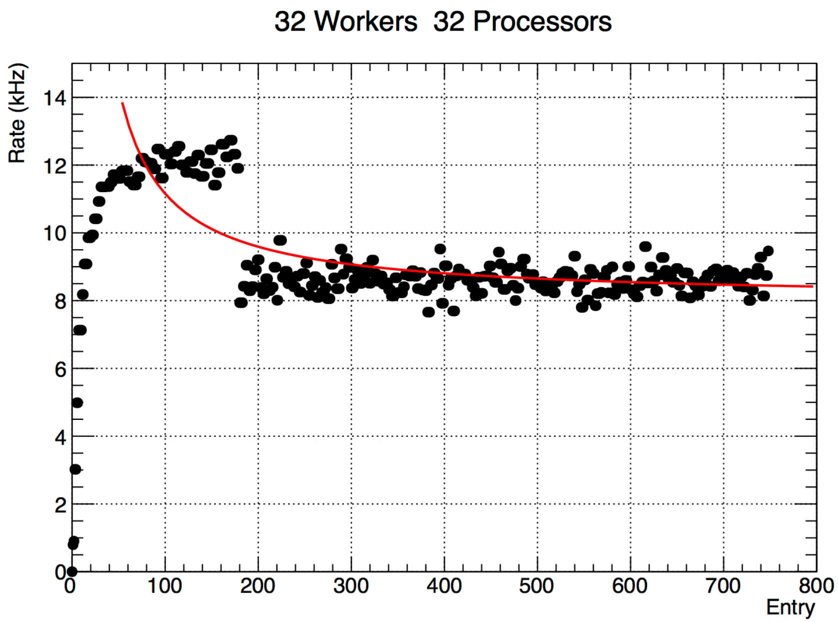
Rate (kHz)	Time/core/event (ms)	Condition
2.5	8.0	All linking enabled
2.9	6.9	All linking except TriggerTime
3.8	5.3	All linking except BORConfig
3.0	6.7	All linking except Config
4.8	4.2	All linking except TriggerTime and BORConfig
5.9	3.4	Hit linking only
8.0	2.5	No Linking

Fitting event rate vs. time

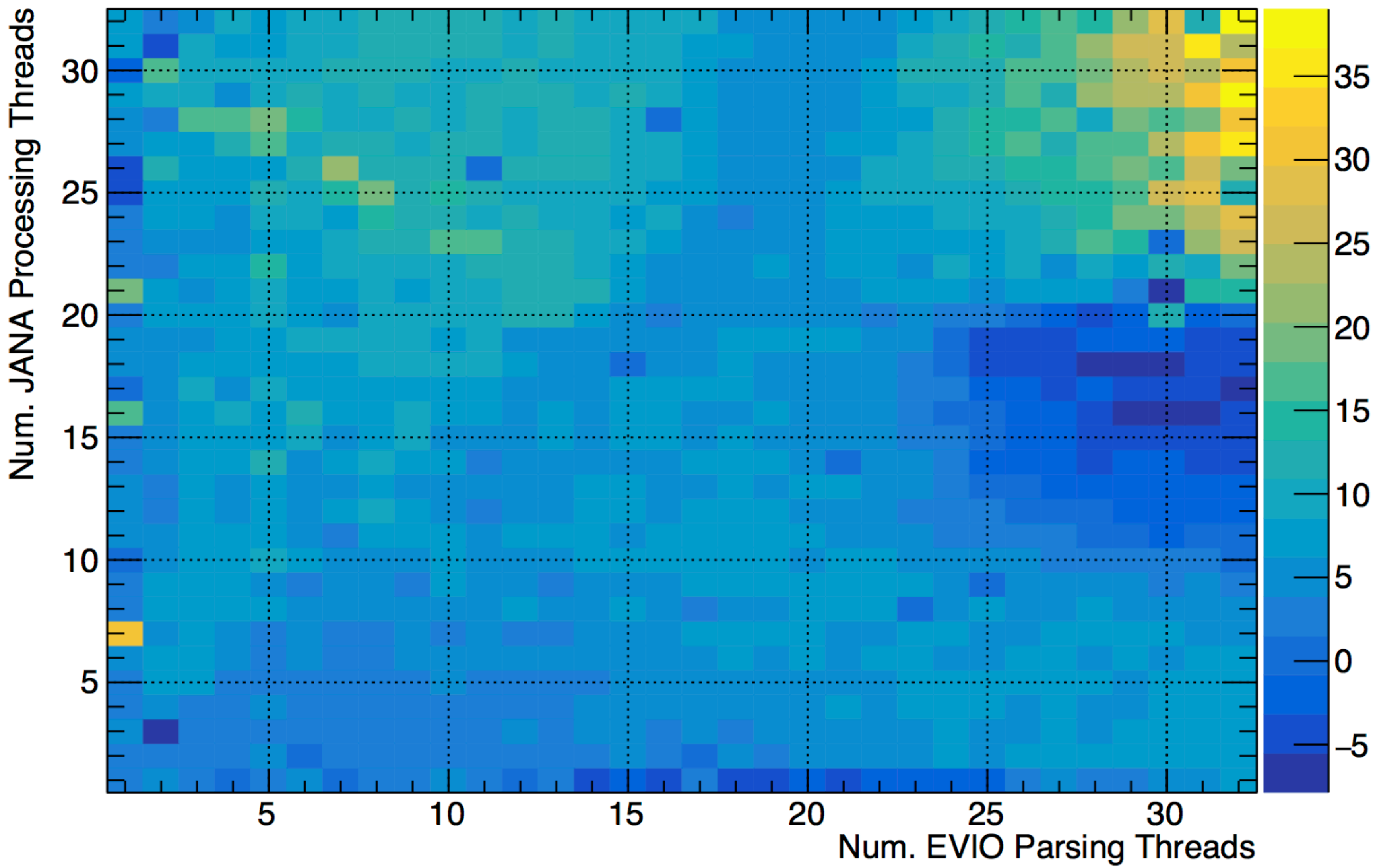
$$R(t) = R_o(1 + Q/t)$$

R_o = asymptotic rate
Q = relaxation term

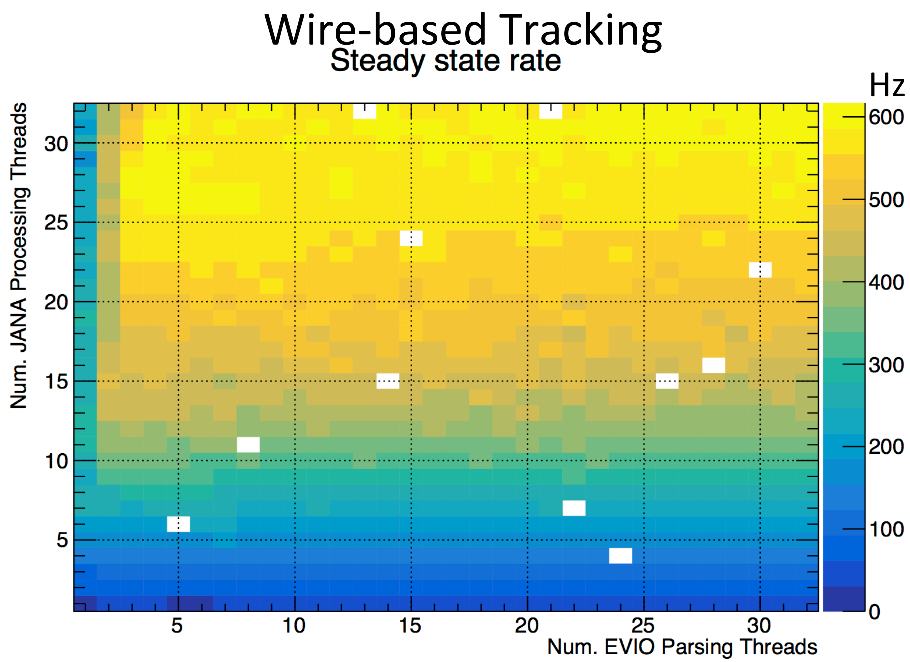


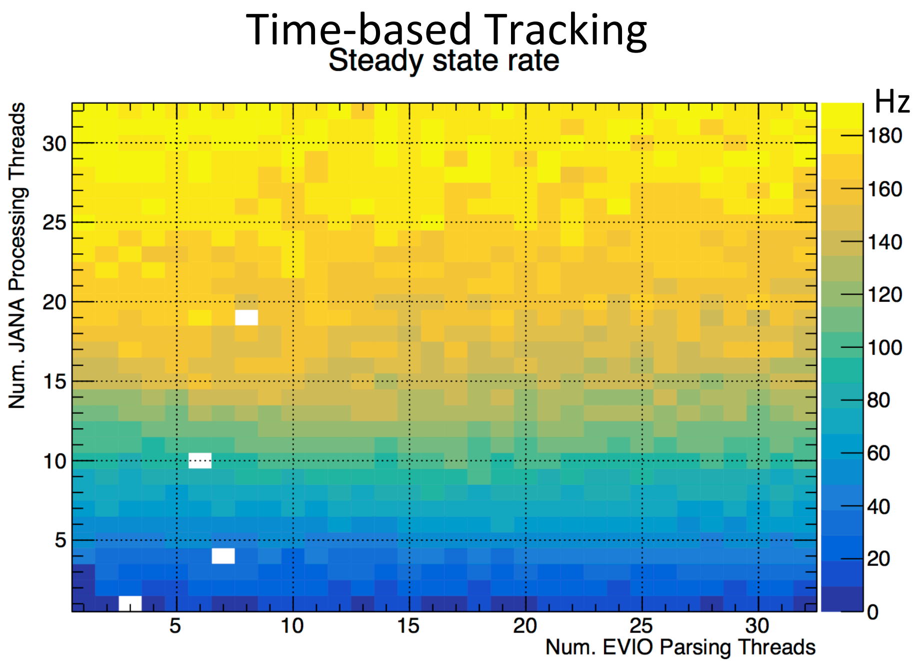


Relaxation term

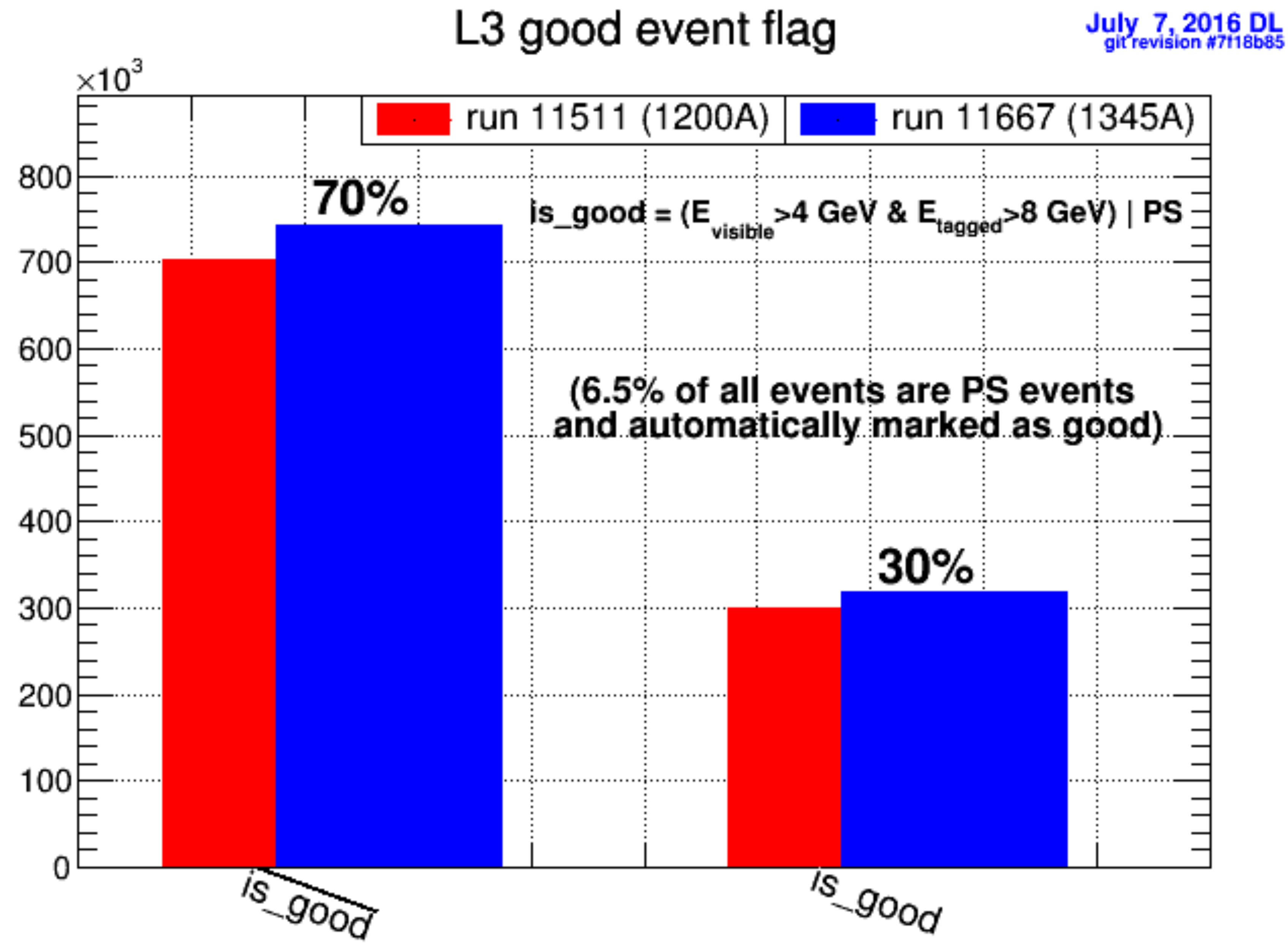


Event rates with tracking

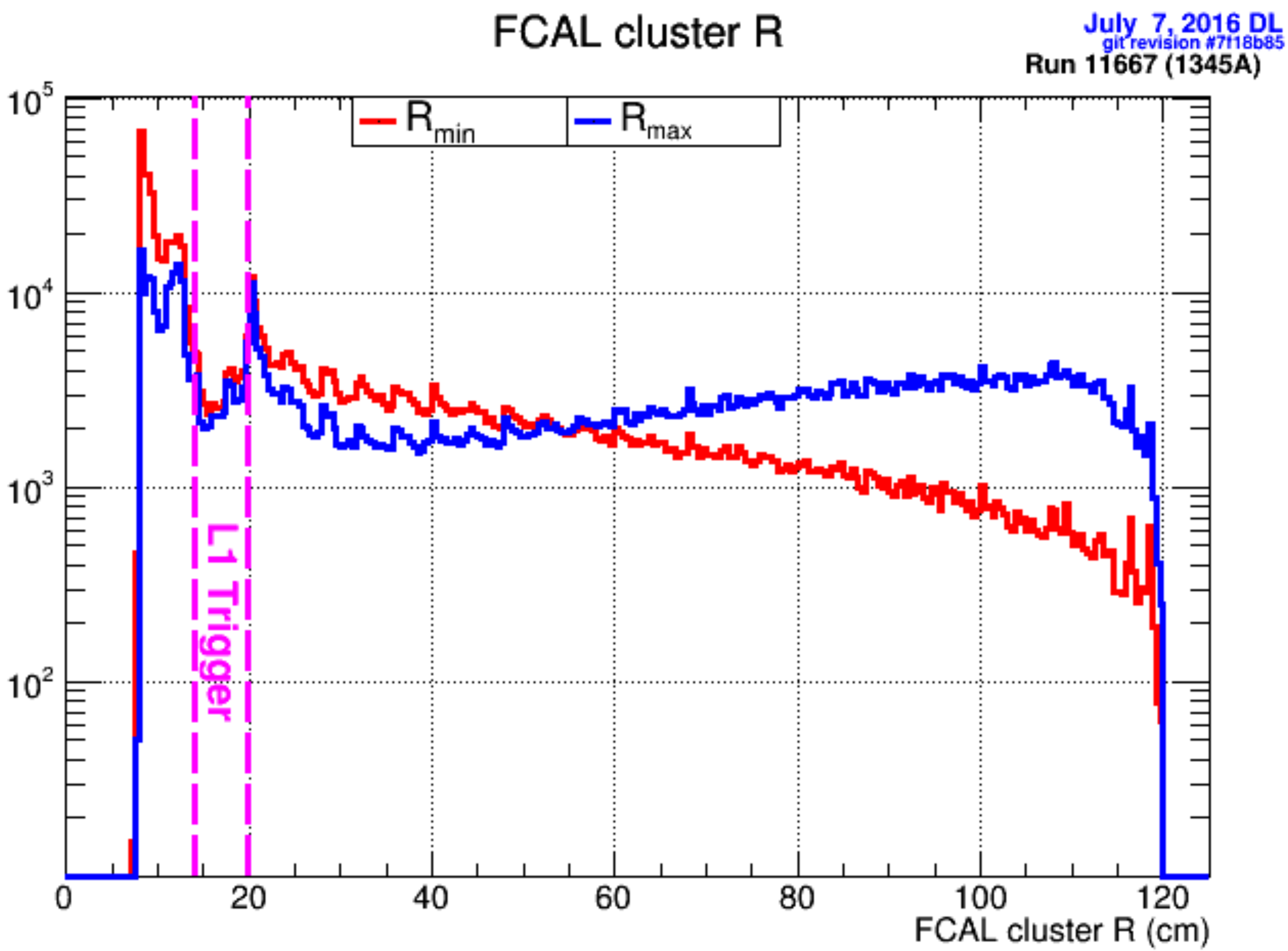




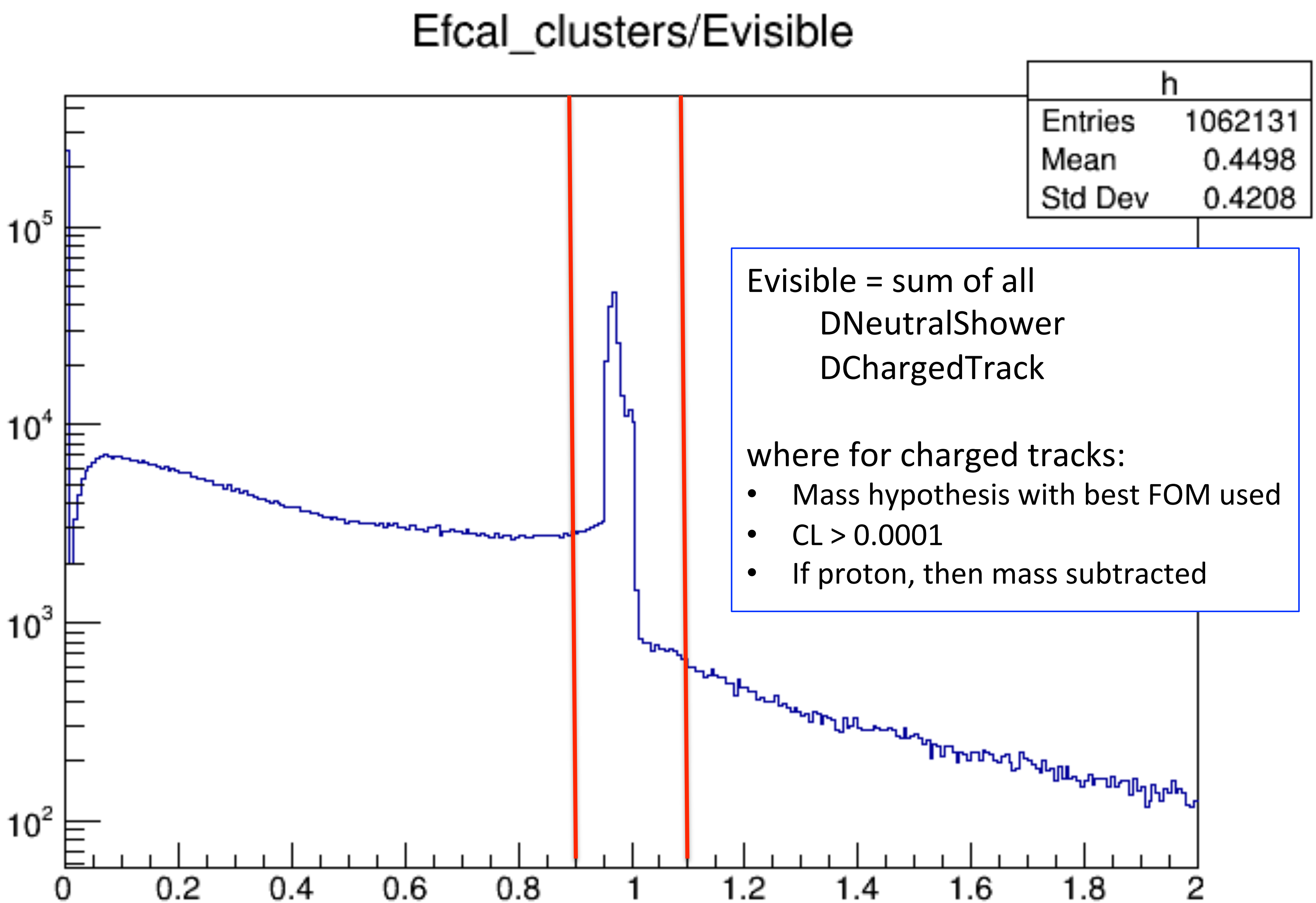
- With associated object linking, parsing threads run about 4 times slower
- Single parsing thread with full linking: ~250Hz



L3 good event flag
July 7, 2016 DL
git revision #7f18b85
×10³
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



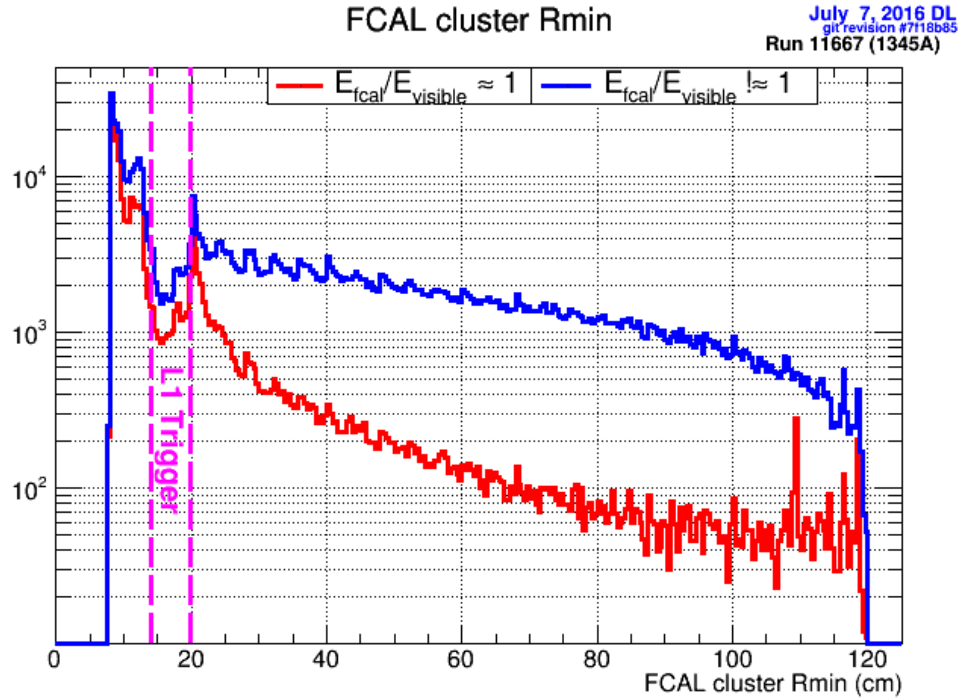
FCAL cluster R
July 7, 2016 DL
git revision #7f18b85
Run 11667 (1345A)
Rmin
Rmax
L1 Trigger
10^5
10^4
10^3
10^2
0
20
40
60
80
100
120
FCAL cluster R (cm)

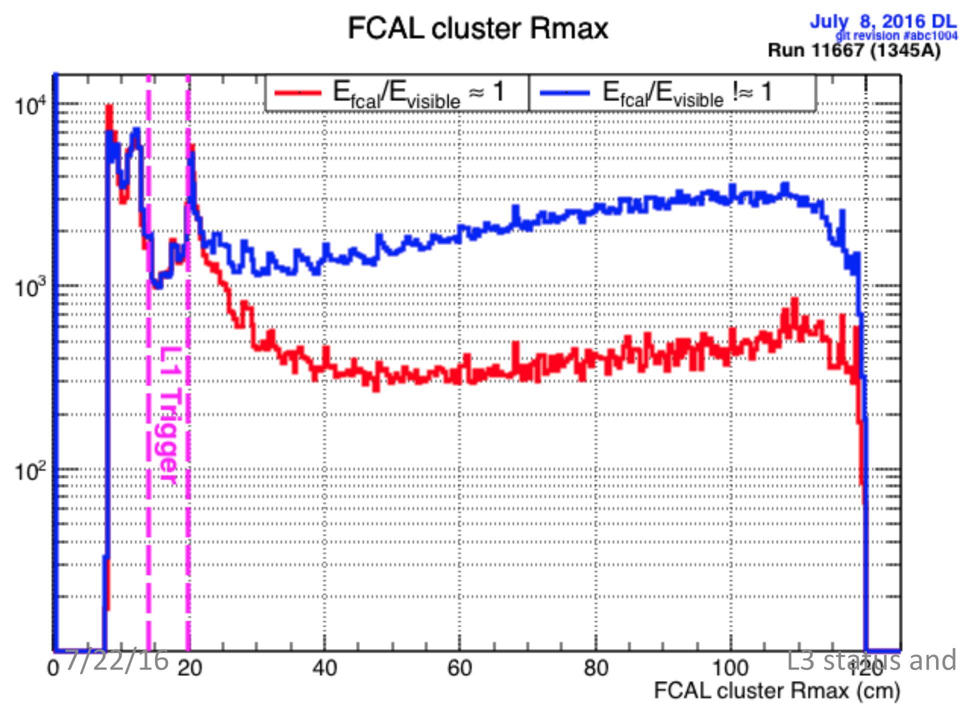


Evisible = sum of all
DNeutralShower
DChargedTrack

where for charged tracks:

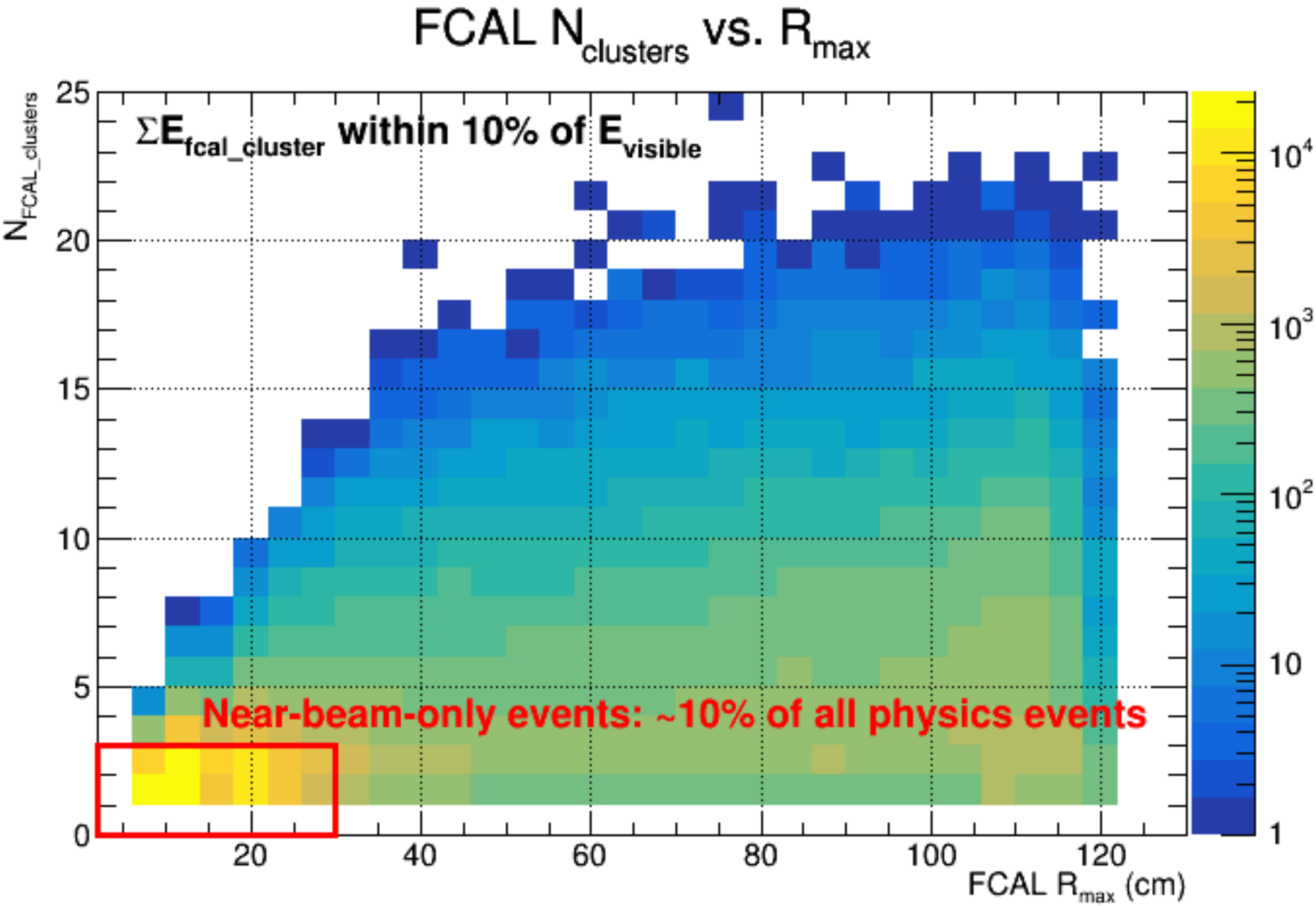
- Mass hypothesis with best FOM used
- CL > 0.0001
- If proton, then mass subtracted

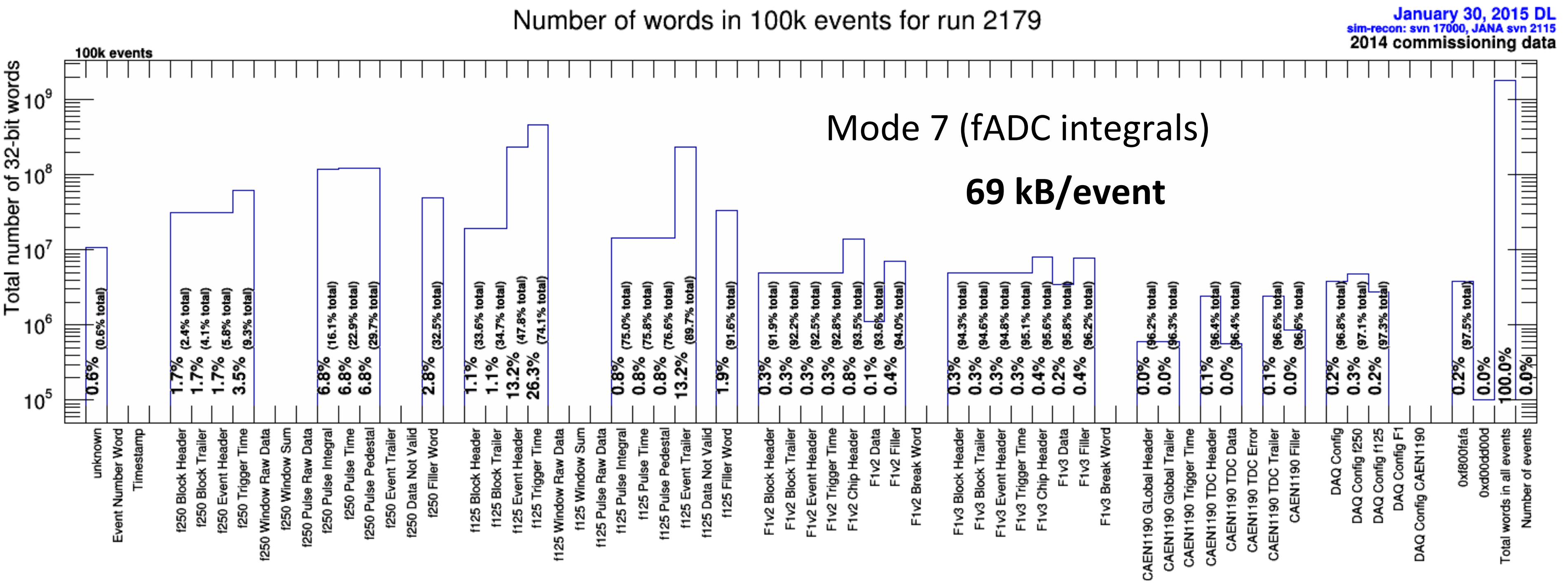


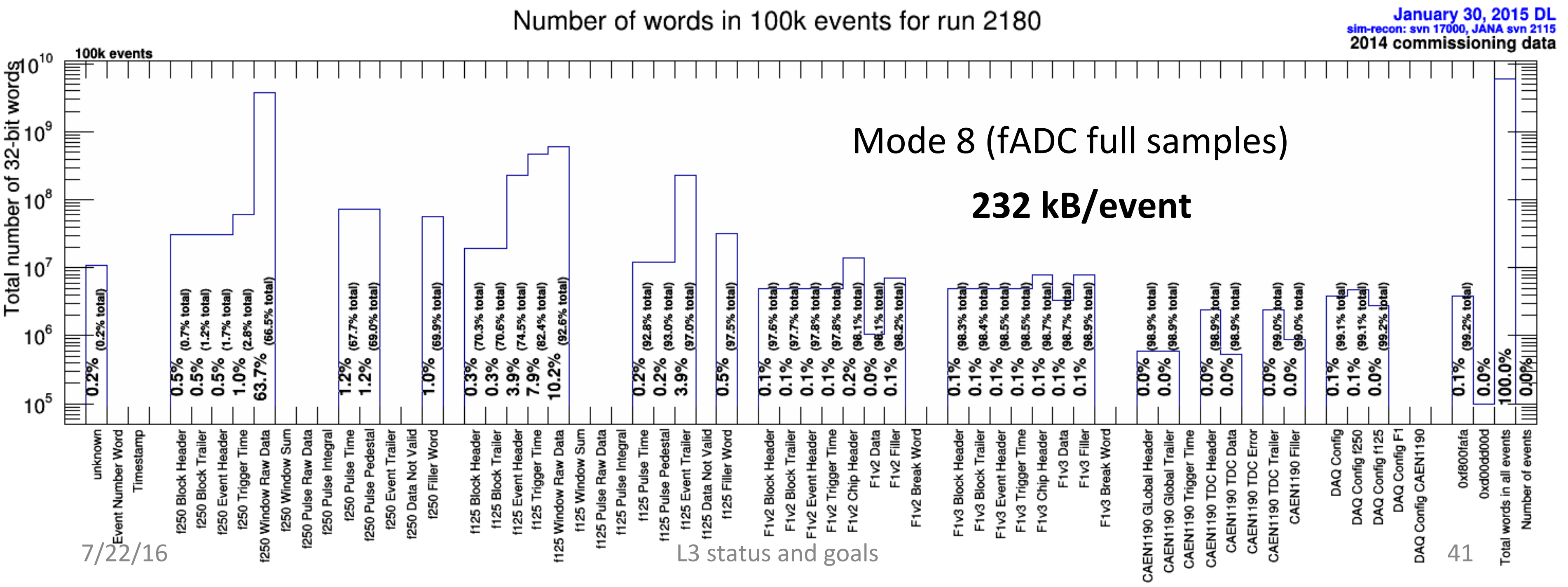


FCAL Rmin and Rmax

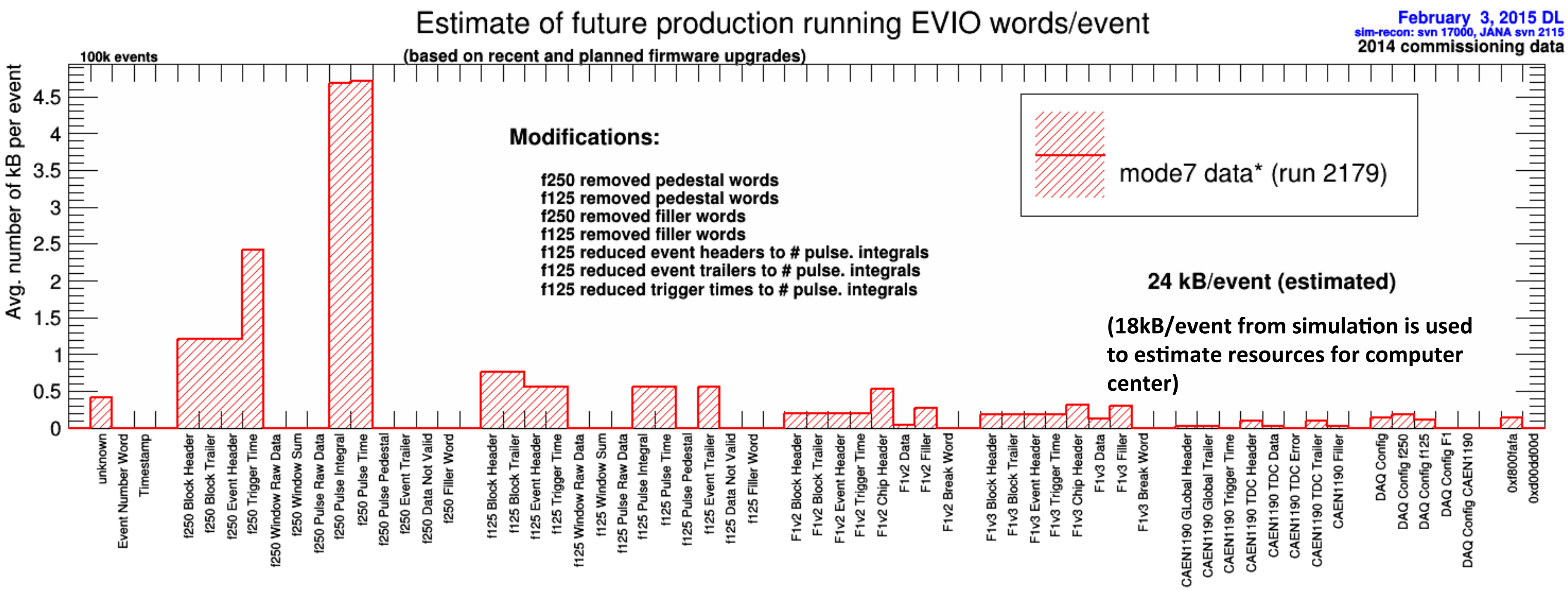
for when most of Evisible is inside (outside) of FCAL


FCAL N$_{clusters}$ vs. R$_{max}$
$\Sigma E_{fcal\_cluster}$ within 10% of $E_{visible}$
Near-beam-only events: ~10% of all physics events
$N_{FCAL\_clusters}$
FCAL R_{max} (cm)
0
5
10
15
20
25
20
40
60
80
100
120
1
10
10^2
10^3
10^4


Number of words in 100k events for run 2179
January 30, 2015 DL
sim-recon: svn 17000, JANA svn 2115
2014 commissioning data
100k events
Total number of 32-bit words
Mode 7 (fADC integrals)
69 kB/event
unknown
Event Number Word
Timestamp
f250 Block Header
f250 Block Trailer
f250 Event Header
f250 Trigger Time
f250 Window Raw Data
f250 Window Sum
f250 Pulse Raw Data
f250 Pulse Integral
f250 Pulse Time
f250 Pulse Pedestal
f250 Event Trailer
f250 Data Not Valid
f250 Filler Word
f125 Block Header
f125 Block Trailer
f125 Event Header
f125 Trigger Time
f125 Window Raw Data
f125 Window Sum
f125 Pulse Raw Data
f125 Pulse Integral
f125 Pulse Time
f125 Pulse Pedestal
f125 Event Trailer
f125 Data Not Valid
f125 Filler Word
F1v2 Block Header
F1v2 Block Trailer
F1v2 Event Header
F1v2 Trigger Time
F1v2 Chip Header
F1v2 Data
F1v2 Filler
F1v2 Break Word
F1v3 Block Header
F1v3 Block Trailer
F1v3 Event Header
F1v3 Trigger Time
F1v3 Chip Header
F1v3 Data
F1v3 Filler
F1v3 Break Word
CAEN1190 GLobal Header
CAEN1190 Global Trailer
CAEN1190 Trigger Time
CAEN1190 TDC Header
CAEN1190 TDC Data
CAEN1190 TDC Error
CAEN1190 TDC Trailer
CAEN1190 Filler
DAQ Config
DAQ Config f250
DAQ Config f125
DAQ Config F1
DAQ Config CAEN1190
0xf800fafa
0xd00dd00d
Total words in all events
Number of events


Number of words in 100k events for run 2180
January 30, 2015 DL
sim-recon: svn 17000, JANA svn 2115
2014 commissioning data
100k events
Total number of 32-bit words
Mode 8 (fADC full samples)
232 kB/event

Adjusting profile of 2014 commissioning data based on recent or planned firmware upgrades is used to estimate event size for production data in the future.



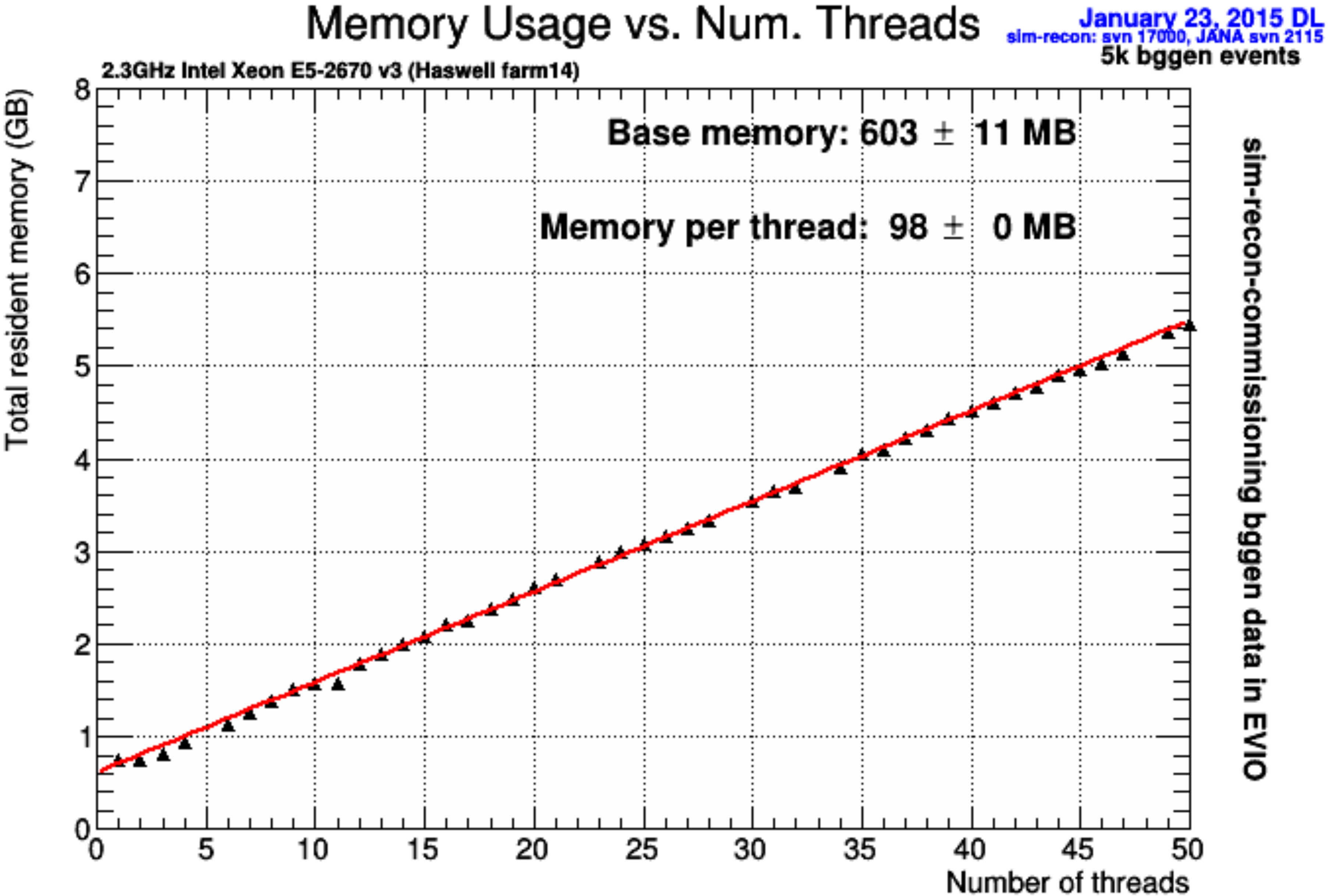
(Additional compression is expected when disentangled data is rebuilt after L3 into an as yet undetermined format.)

Counting house computer systems

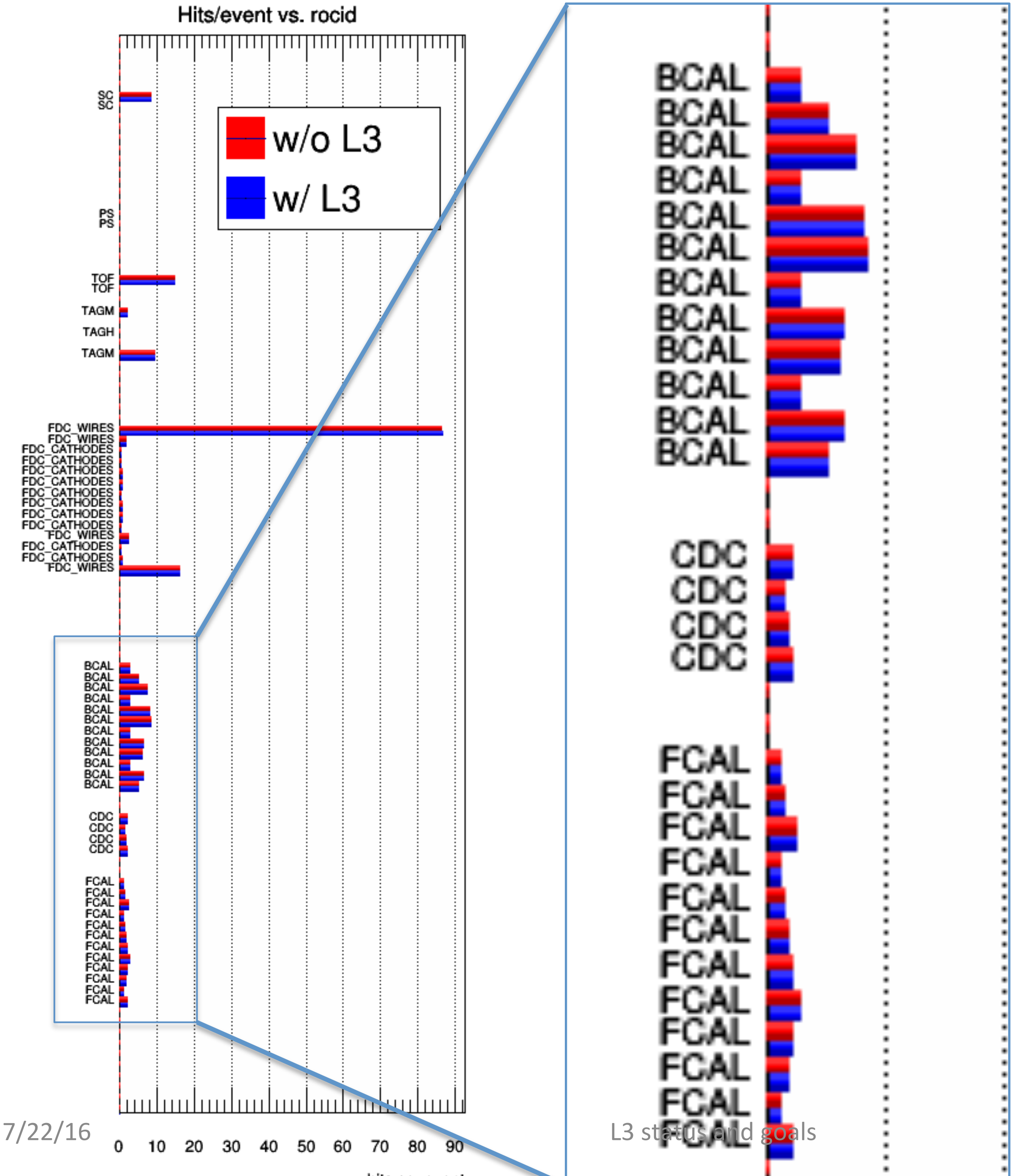
Computer(s)	processor	General Purpose Network	DAQ Network	I.B. Network	comments
gluonfs1	N/A	X			~1.6TB with snapshot backup
gluonraid1-2	Intel E5-2630 v2 @2.6GHz	X	X	X	RAID disk host ER process
gluon01-05	i5-3570 @3.4GHz	X			Shift taker consoles
gluon20-23	AMD 2347	X			Controls 8core
gluon24-30	E5-2420 @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)

- Each 32bit word in the EVIO file tallied to identify what file space is being used for
- Comparison between mode 7 and mode 8 data made

Example: some of the fADC250 word types


Memory Usage vs. Num. Threads
January 23, 2015 DL
sim-recon: svn 17000, JANA svn 2115
5k bggen events
2.3GHz Intel Xeon E5-2670 v3 (Haswell farm14)
Base memory: 603 ± 11 MB
Memory per thread: 98 ± 0 MB
Total resident memory (GB)
Number of threads
sim-recon-commissioning bggen data in EVIO
0
1
2
3
4
5
6
7
8
0
5
10
15
20
25
30
35
40
45
50

name	node	level	Nthr	Nevents	rate (Hz)	idle
gluon101.jlab.org_11057	gluon101.jlab.org	--	32	212874	751.1	75.2%
gluon49.jlab.org_12748	gluon49.jlab.org	--	32	206140	646.7	22.8%
gluon111.jlab.org_5726	gluon111.jlab.org	--	32	206700	643.1	58.1%
gluon110.jlab.org_30100	gluon110.jlab.org	--	32	208726	700.7	4.1%
gluon109.jlab.org_4409	gluon109.jlab.org	--	32	213494	369.9	75.2%
gluon108.jlab.org_10935	gluon108.jlab.org	--	32	247875	390.6	77.0%
gluon107.jlab.org_23963	gluon107.jlab.org	--	32	211054	406.0	72.1%
gluon106.jlab.org_20172	gluon106.jlab.org	--	32	219621	895.5	49.8%
gluon105.jlab.org_10192	gluon105.jlab.org	--	32	212474	507.2	71.1%
gluon104.jlab.org_23134	gluon104.jlab.org	--	32	205814	549.7	66.7%
gluon102.jlab.org_22561	gluon102.jlab.org	--	32	206803	451.5	71.7%
gluon48.jlab.org_18860	gluon48.jlab.org	--	32	214251	519.2	49.7%



Comparing number of hits before and after rewriting with L3