STAR High Level Trigger

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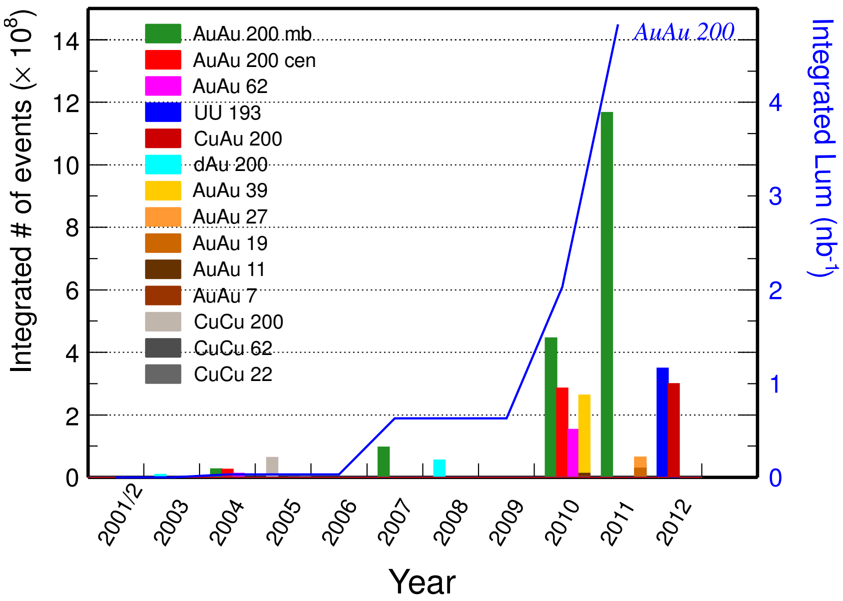
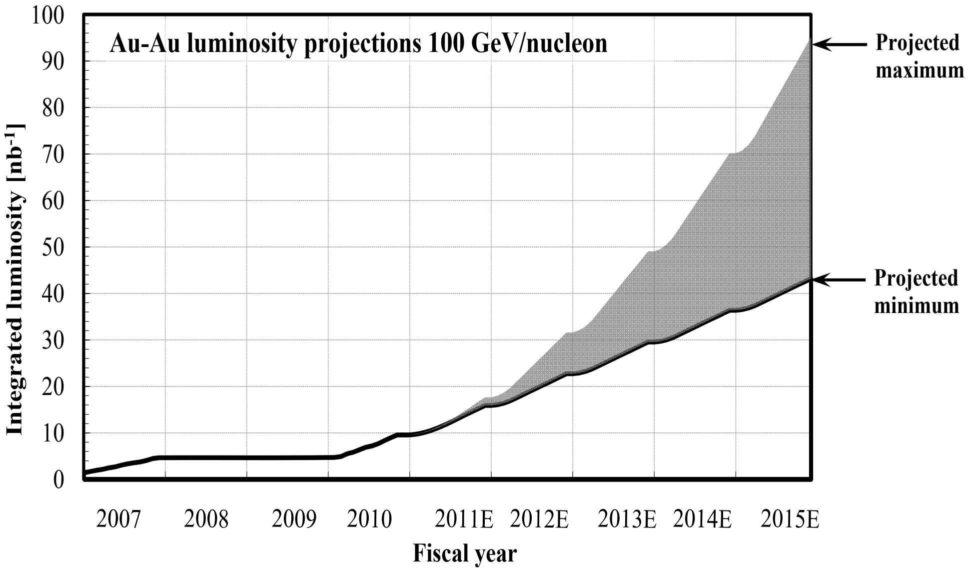
Outline

- Motivation
- Software structure
- Hardware
- Current run status
- Future development

Motivation

- Data-taking keep increasing



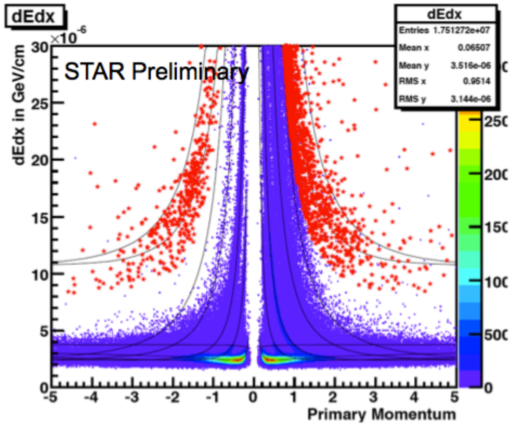


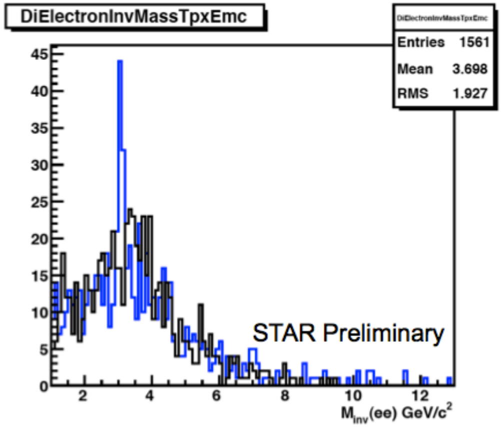
- # of events to tape:
  - Run 14, 2 billion
  - Run 16, 4 billion, difficult to handle with projected computing resources

- Additional reduction on data volume must be done

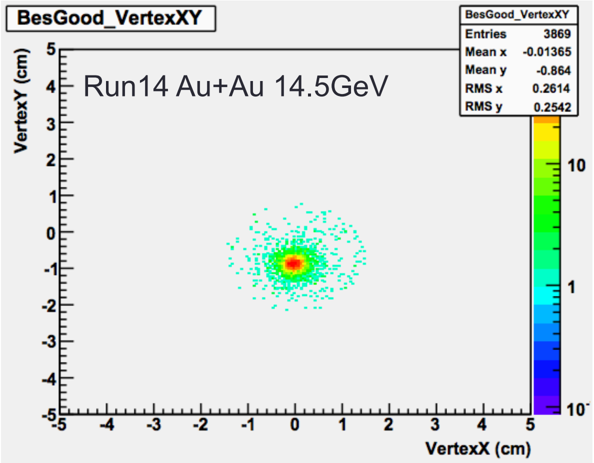
Motivation

- Selection of Rare events
  - heavy fragments, e.g. anti-^{4}He
  - di-electron, e.g. J/Ψ





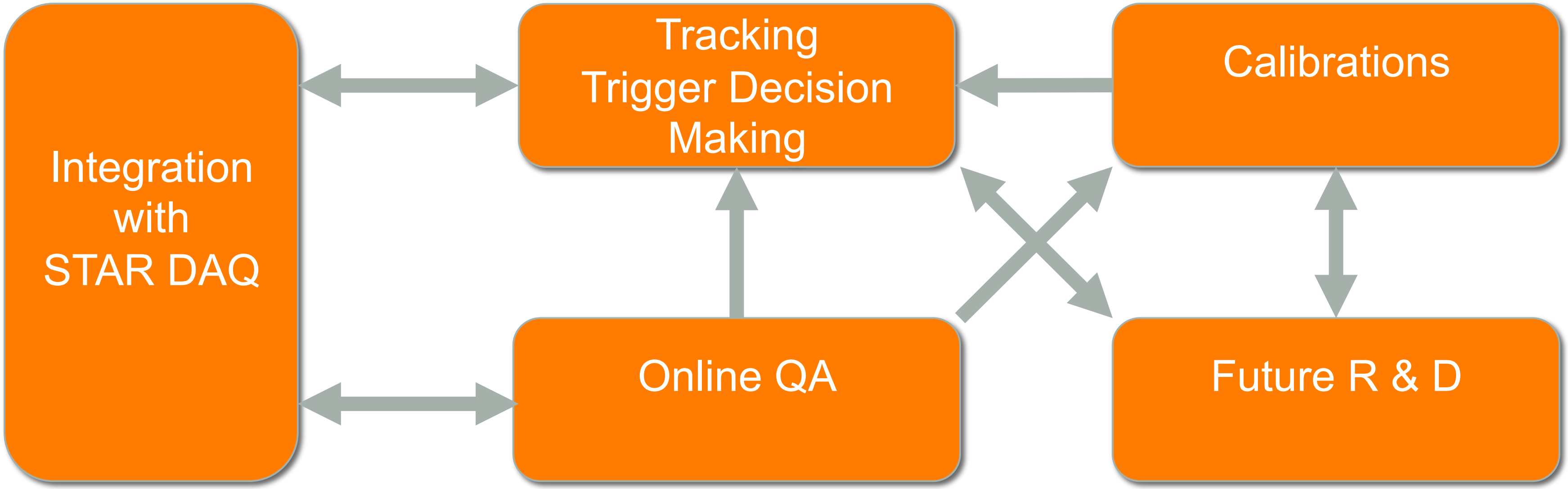
- Online Monitoring



Related history

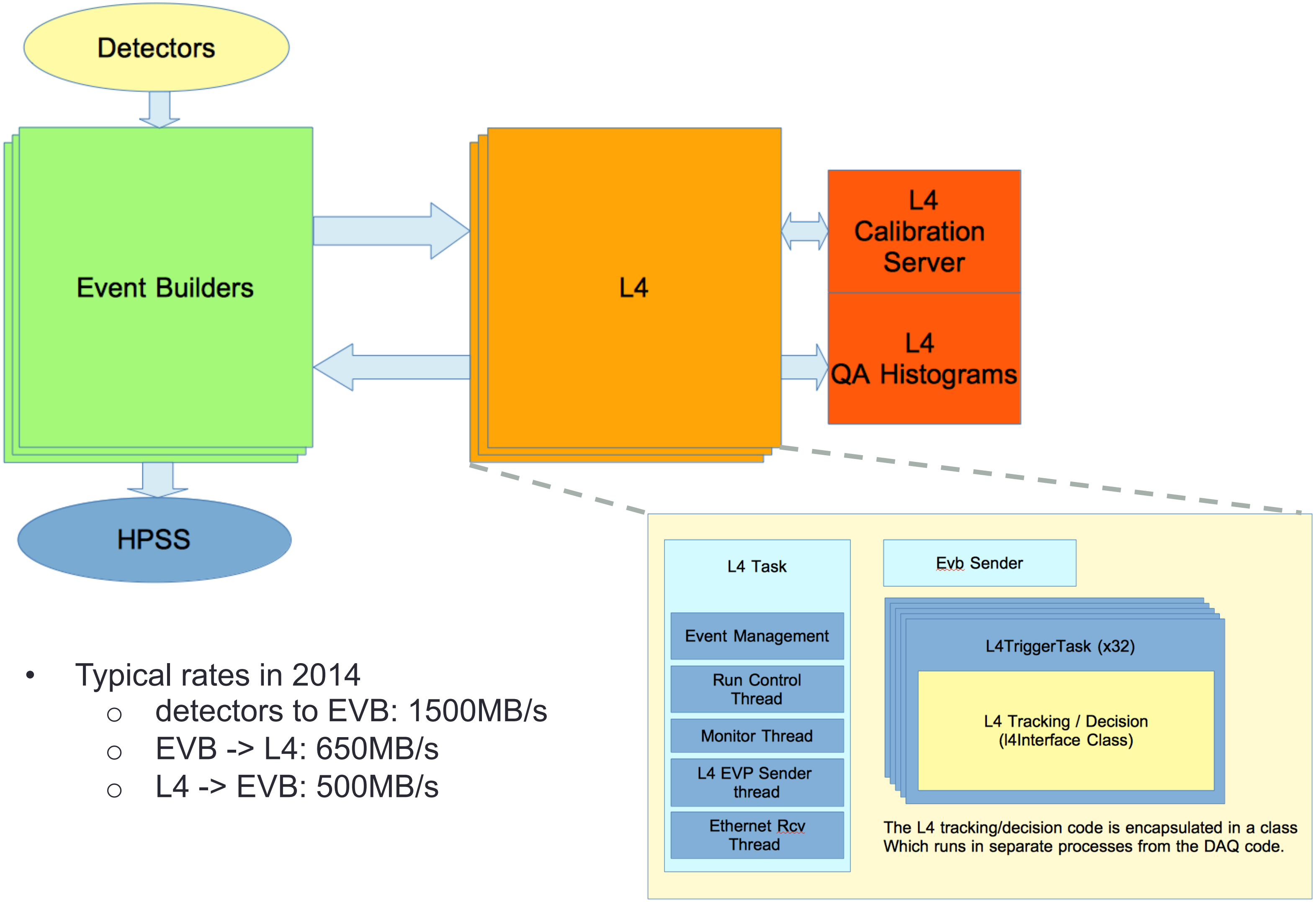
- STAR's old Level-3 trigger system had phased out since ~2002
- Proposal of HLT at 2007 DAQ 1k workshop.
- Proof of principle in 2008.
- Prototype in 2009 with real data taking (DAQ 1k installed in 2009).
- In function in 2010, 2011 and 2012. (Made significant contribution to the discovery of anti-^{4}He, which was published in Nature)
- Re-built in 2013 with independent farm and switched to CA tracker
- Run as a real trigger in 2014

HLT Division by Tasks



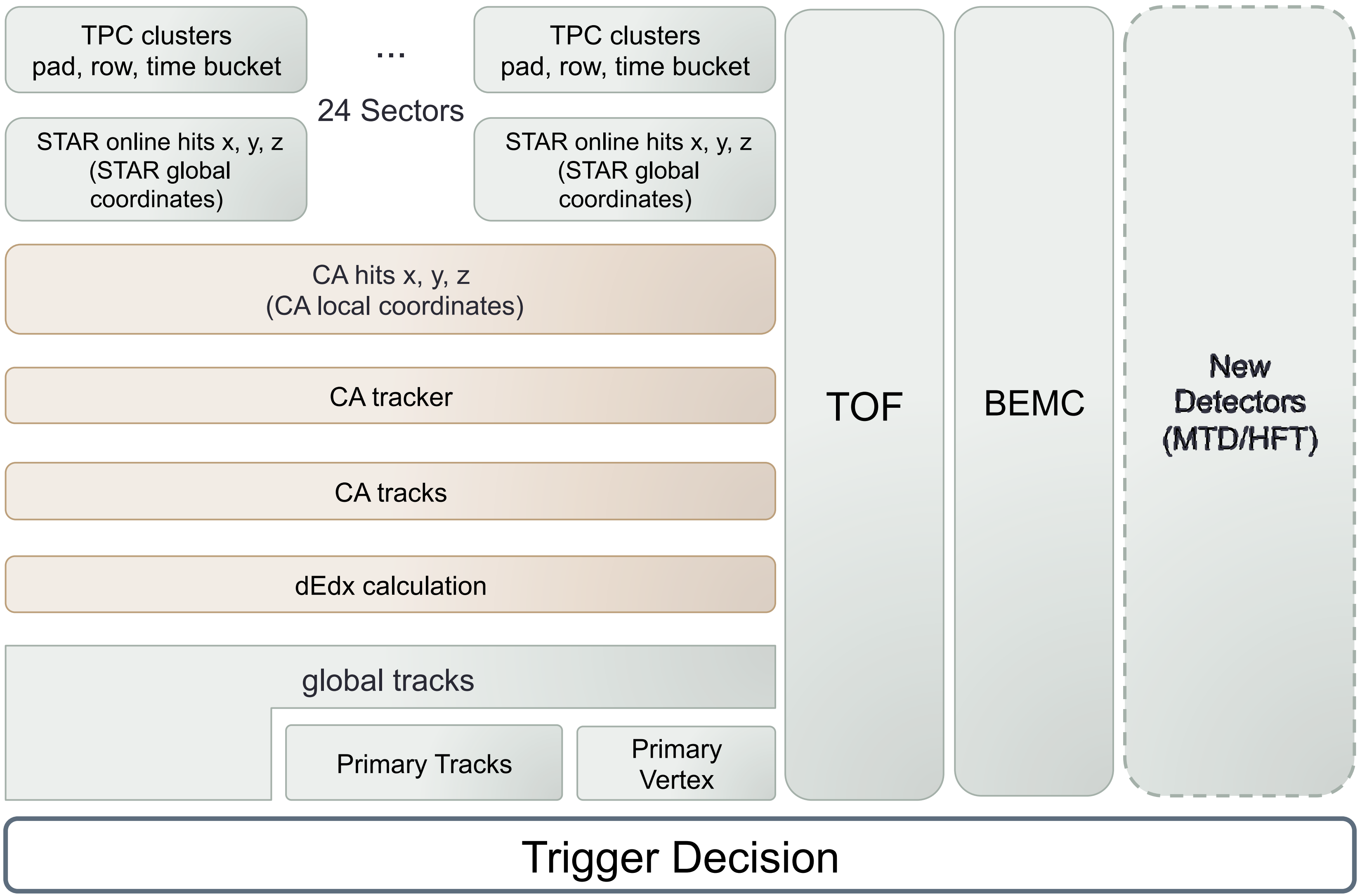
STAR HLT Integration with DAQ

- STAR HTL is run as level-4 trigger in DAQ system



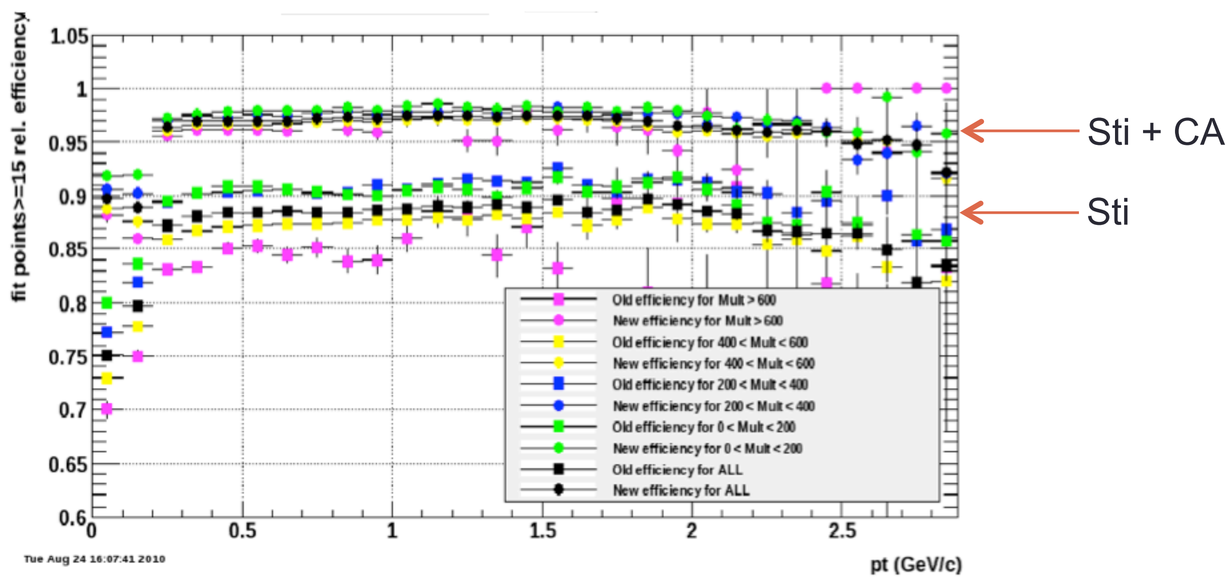
- Typical rates in 2014
  - detectors to EVB: 1500MB/s
  - EVB -> L4: 650MB/s
  - L4 -> EVB: 500MB/s

STAR HLT software structure



TPC Tracking

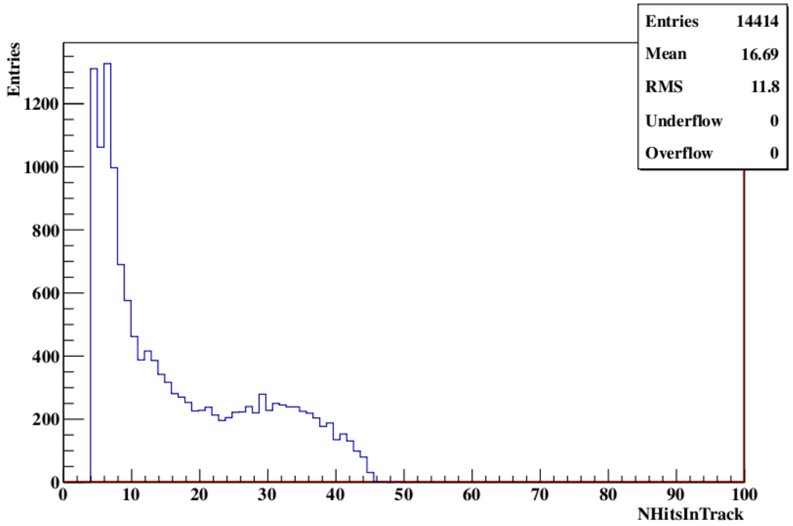
- Previous HLT TPC tracker is based on conformal mapping method,
P. Yepes, NIM A, **380**, 582 (1996).
- Switch to CA tracker since 2013
- Vectorized via Vc
- ~50ms/event for Au+Au 200GeV collisions

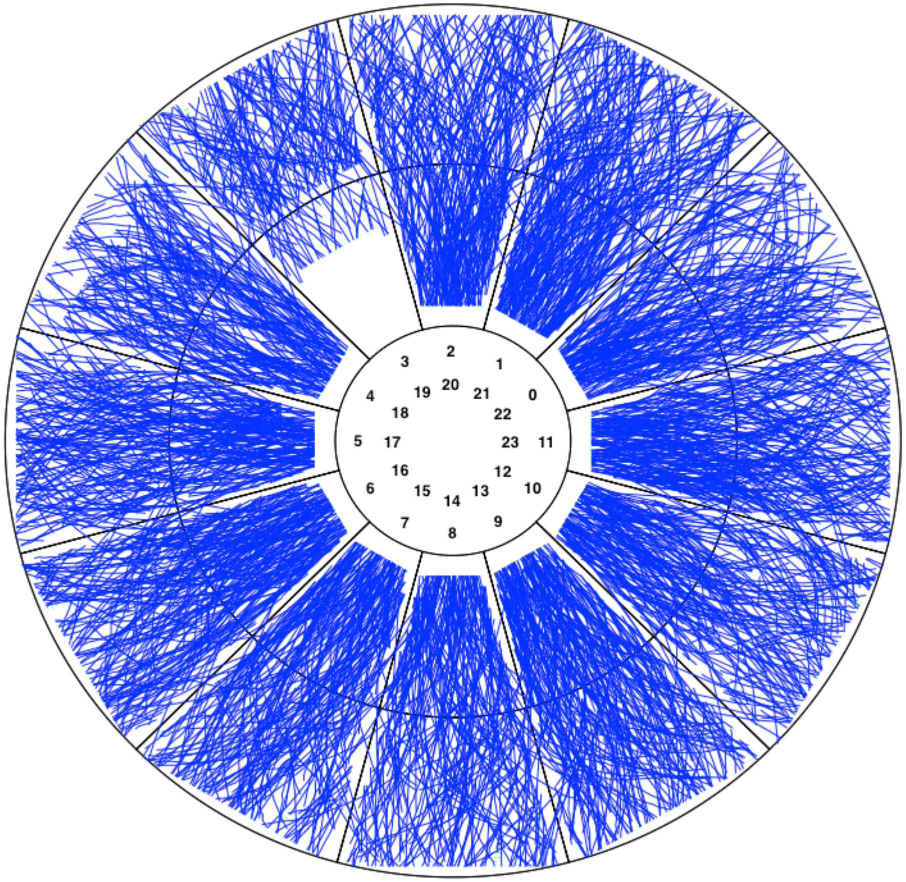


- Efficiency for global tracks +7-9%
- squares for Sti tracker
- dots for Sti+CA tracker

TPC tracking with CA tracker

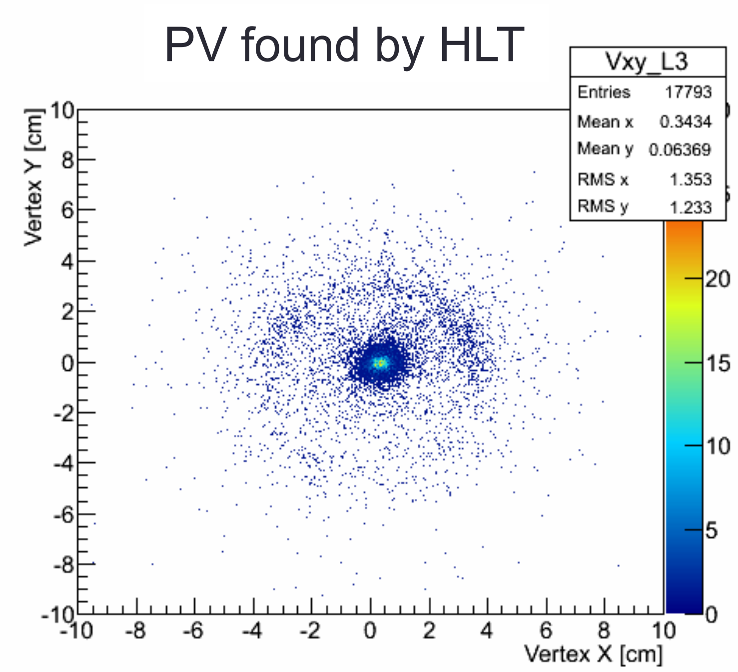
- CA tracking in HLT framework
  - sector tracking + merging

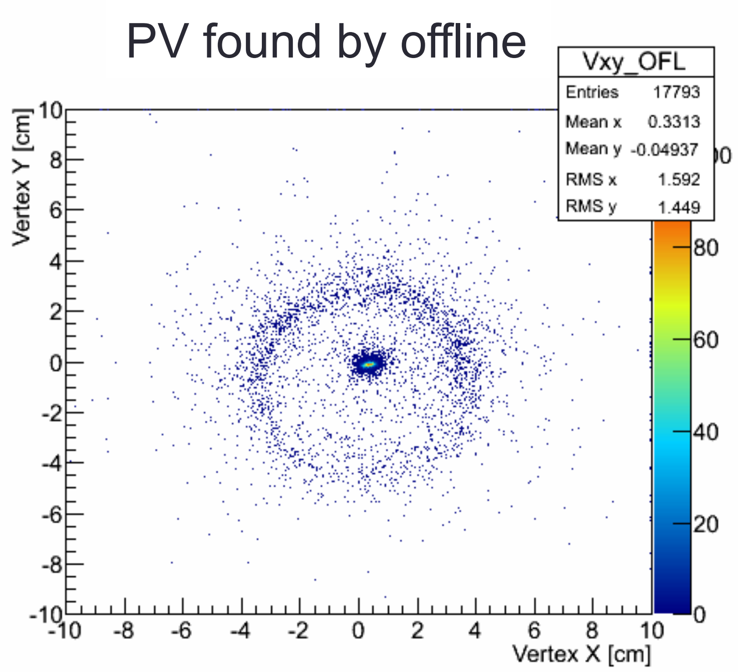




Primary Vertex finding in STAR HLT

- STAR HLT Primary Vertex finder uses a iterative average of DCA points of global tracks
- select beam-beam collision events in low energy collisions, as beam-pipe background cannot be rejected by low level triggers
- select events in the center of TPC/HFT



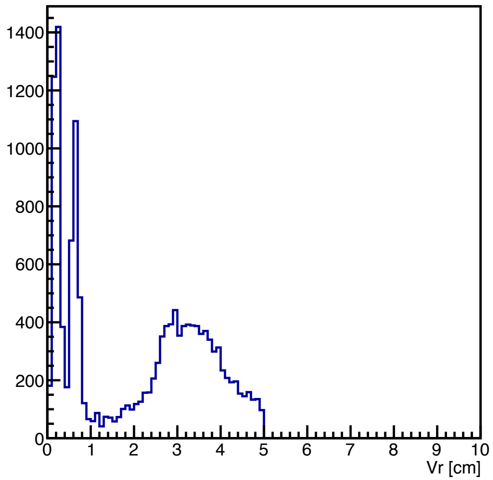


Test the KFParticle PV finder

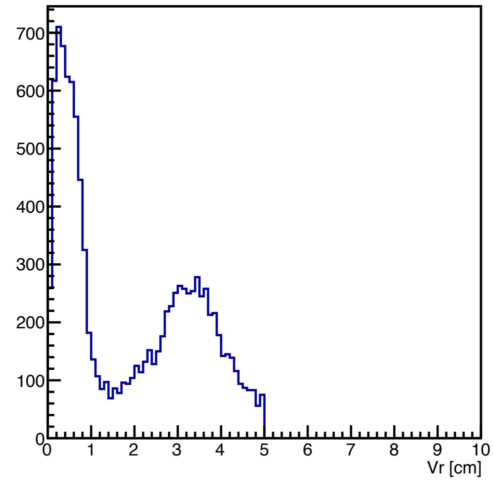
- Better Vr resolution for beam-beam collisions

$$V_r = \sqrt{V_x^2 + V_y^2}$$

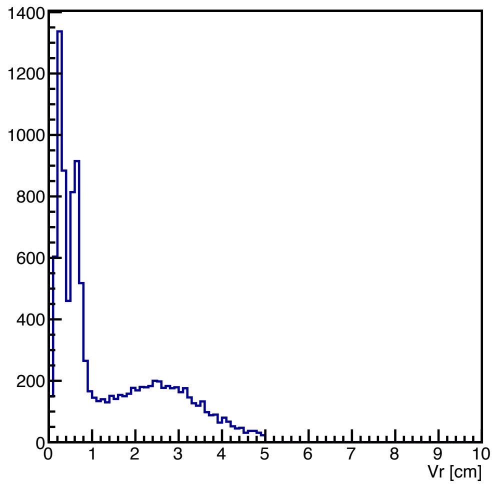
offline PV



HLT PV



KF PV



STAR HLT Hardware

- Hardware Configuration
  - Nine nodes (will be expanded)
  - 164 cores @ 2.6GHz $\times$ 2 hyper threading
  - 832 GB RAM
  - 2 $\times$ 10Gbit NIC per node running at 1Gbit
  - 5 $\times$ 2 slots ready for Xeon Phi / GPGPU

  - One node loan from Intel Inc. Configured with two Xeon Phi cards. Very useful testing bed.

Run14 Au+Au @ 14.5GeV

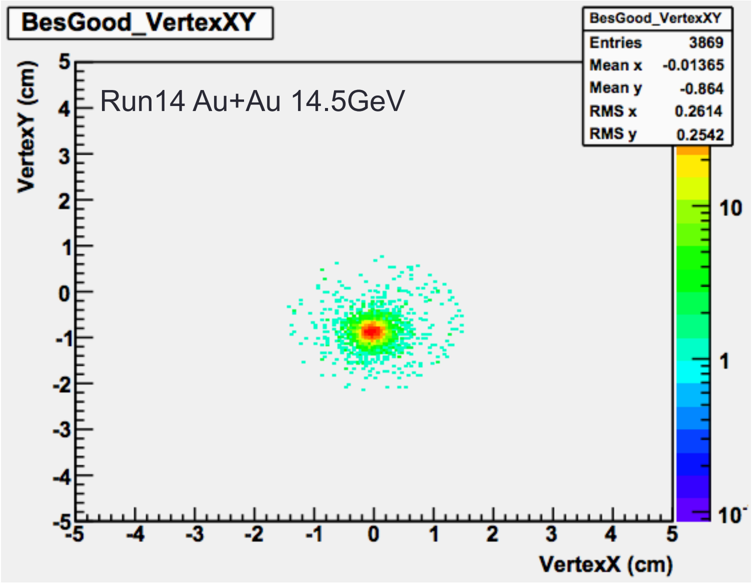
- Tag "good" events
  - hlt-good-vpd

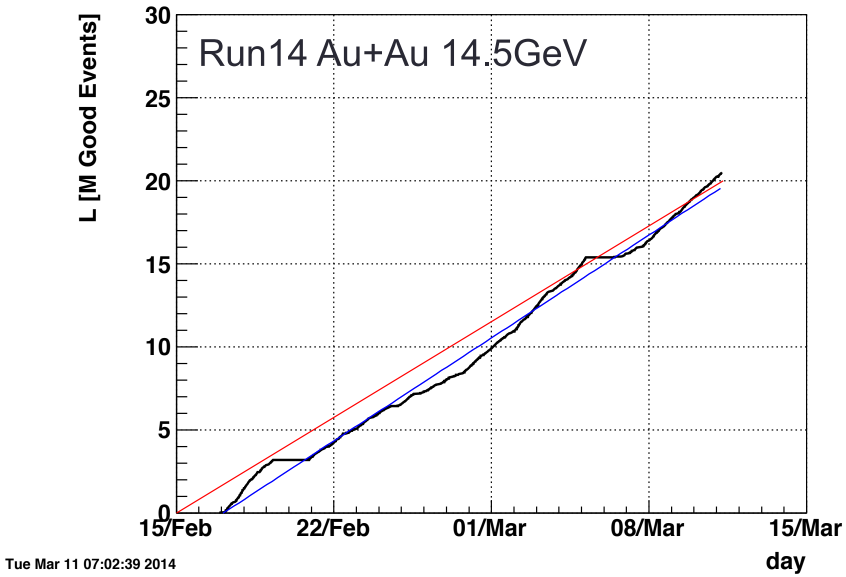
$$nTracks > 5$$
$$|V_z| < 30 \text{ cm}$$
$$\sqrt{V_x^2 + (V_y + 0.7)^2} < 1.5 \text{ cm}$$

  - beam center (0, -0.7)

- Provide live feedback to CAD for optimizing good-collision rate

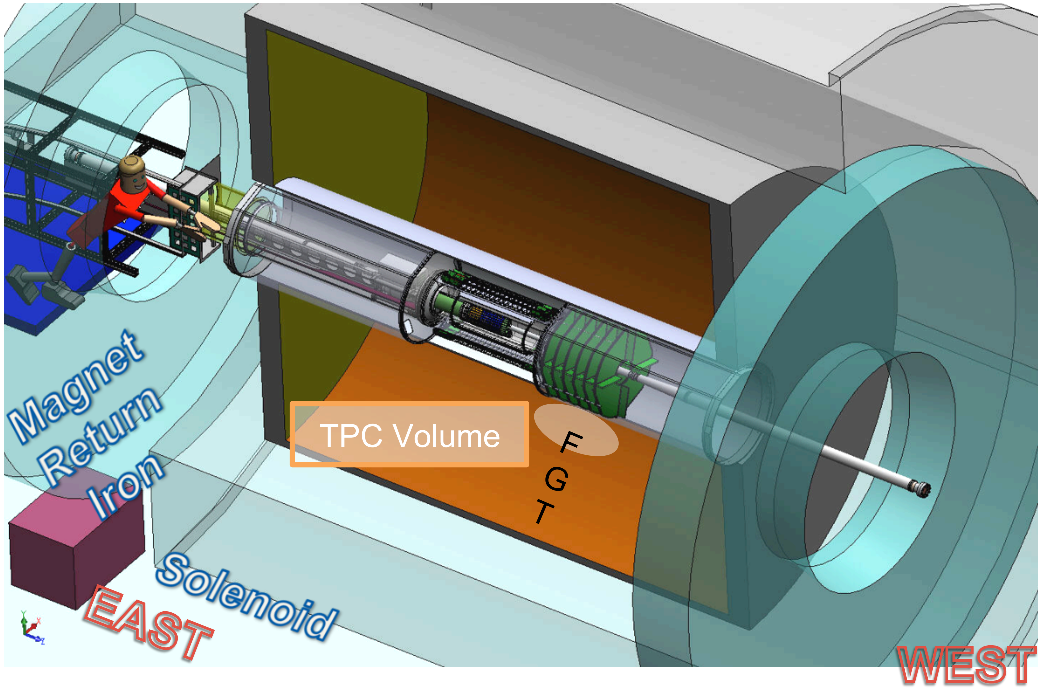
- Useful for tracking run-progress





Run14 Au+Au @ 200GeV

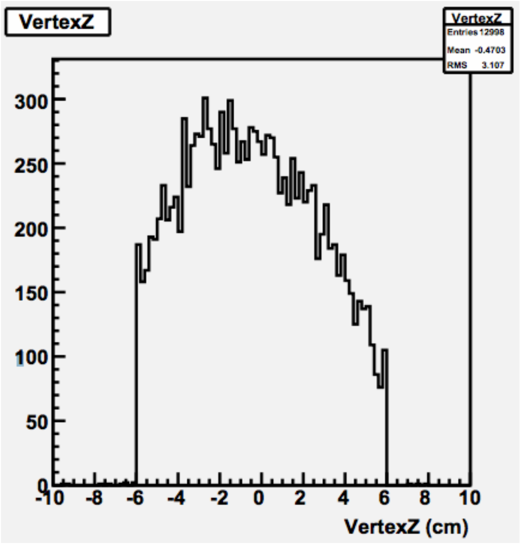
- Heavy flavor tracker is fully installed in Run14
- SSD, IST and two layers of pixel (PXL)
- PXL covers ±10 cm in z-direction
- Need collisions in the center to ensure a good acceptance

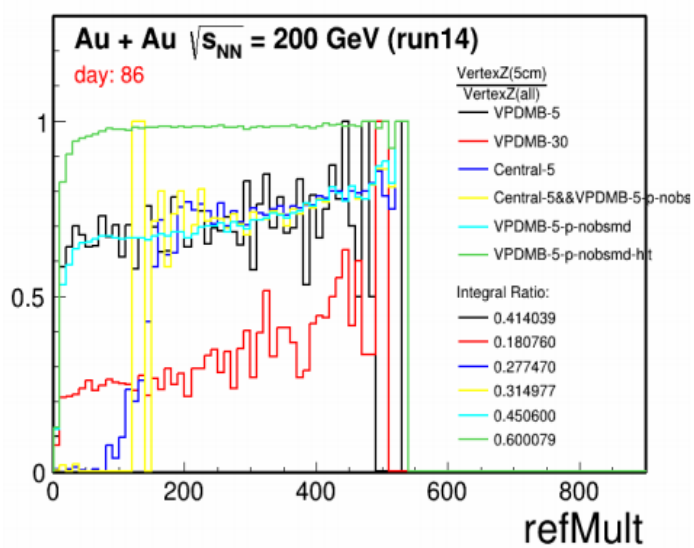


Run14 Au+Au @ 200GeV

- Main trigger: |VPD Vz| < 5cm with limited resolution
- Additional cuts provided by HLT

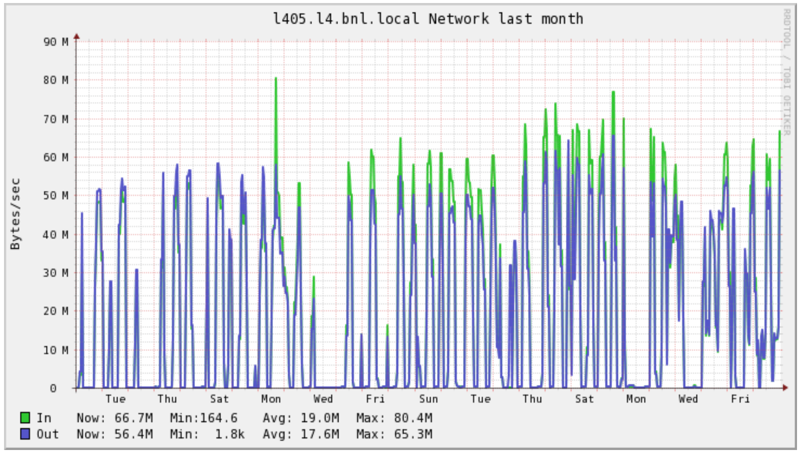
$$nTracks > 5$$
$$|V_z| < 5 \text{ cm (change to 6 later)}$$
$$\sqrt{V_x^2 + (V_y + 0.7)^2} < 1.5 \text{ cm}$$



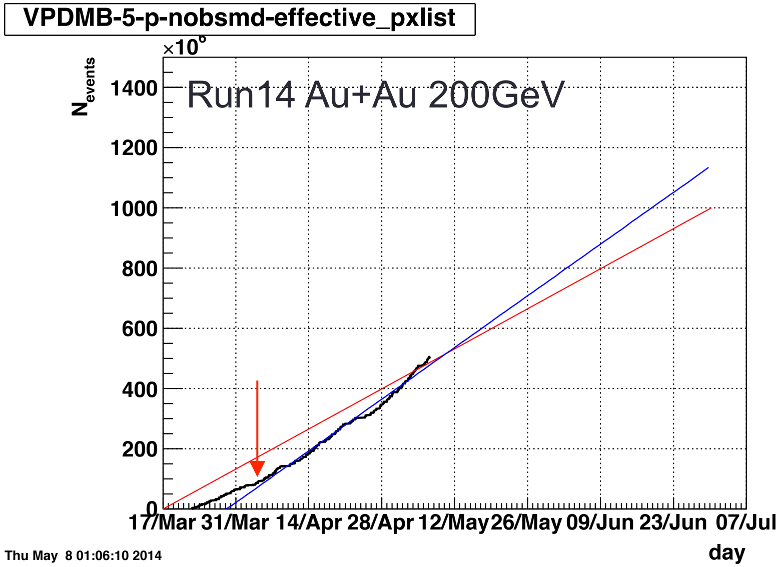


Run14 Au+Au @ 200GeV

- Serve as a tagger at the beginning. Tag events with good HFT acceptance
- Start to **reject** events since Apr 7th. Help HFT program to use bandwidth more efficiently



Green: data sent in to HLT machine
Blue: data sent out from HLT machine



Run14 Au+Au @ 200GeV

Trigger	DAQ Evts	DAQ Hz	L0 Evts	L0 Hz	Sca Hz	Sca Dead	Built	Xpress	Abt	Err
singlemuon	25818	94	25960	68	223	11 %	25817	25817	0	1
dimuon	142664	450	143386	389	574	12 %	142664	142664	0	0
e-mu	11844	37	11904	32	114	18 %	11843	11843	0	1
mtd-cosmic1	141	0	142	1	10	30 %	141	141	0	0
mtd-cosmic2	107	1	107	0	9	22 %	107	107	0	0
mtd-cosmic3	126	0	128	1	16	31 %	126	126	0	0
VPDMB-5-p-nobsmd	316	2	317	1	1109	9 %	261	0	55	0
VPDMB-5-p-nobsmd-hltheavyfrag	350436	1155	351866	1017	1109	9 %	208	208	350223	5
VPDMB-5-p-nobsmd-hltDiElectron	350436	1155	351866	1017	1109	9 %	669	669	349762	5
VPDMB-5	312	1	313	1	1345	14 %	312	0	0	0
VPDMB-5-ssd	3073	8	3091	9	1345	15 %	3073	3073	0	0
VPDMB-30	288	2	288	0	7018	12 %	288	0	0	0
MB-mon	415	1	418	1	43122.1	14 %	415	0	0	0
ZDC-mon	292	2	293	1	34941.1	12 %	292	0	0	0
VPD-ZDC-novtx-mon	310	0	311	1	18521	12 %	310	0	0	0
Central-5	7097	27	7142	22	202	16 %	7097	0	0	0
Central-mon	297	1	299	1	2523	12 %	297	0	0	0
Central-5-hltheavyfrag	7097	27	7142	22	202	16 %	14	14	7083	0

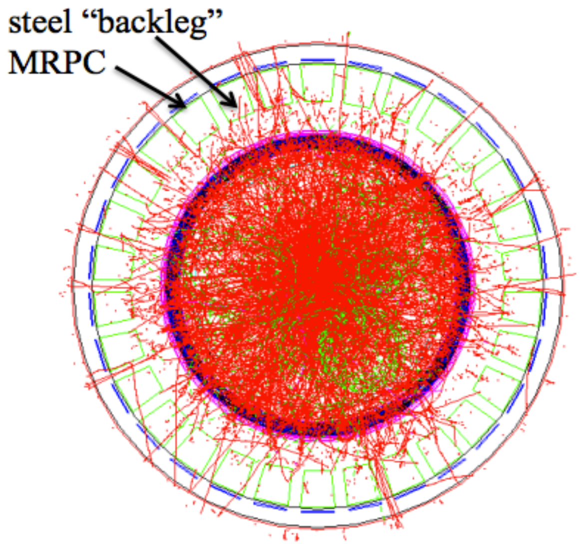
Trigger	DAQ Evts	DAQ Hz	L0 Evts	L0 Hz	Sca Hz	Sca Dead	Built	Xpress	Abt	Err
Central-5-hltDiElectron	7097	27	7142	22	202	16 %	79	79	7018	0
BHT2*VPDMB-30	9418	26	9451	25	28	11 %	9417	0	0	1
BHT3	3715	12	3727	12	13	15 %	3715	0	0	0
BHT3-L2Gamma	3715	12	3727	12	13	15 %	1442	1442	2273	0
EHT	2074	8	2085	9	9	0 %	2074	0	0	0
UPC-main	9716	34	9741	27	207	18 %	9715	9715	0	1
UPC-topo	589	1	590	2	2927	18 %	589	589	0	0
UPC-highG	3046	9	3058	9	9788	20 %	3046	3046	0	0
UPC-jpsi-B	52	0	53	0	0	0 %	52	52	0	0
VPDMB-5-nobsmd	319	1	320	0	1345	11 %	319	0	0	0
VPDMB-5-p-nobsmd-hlt	350436	1155	351866	1017	1109	9 %	209417	0	141014	5
ZDC_fast_prepost	3396	10	3430	10	53209.1	0 %	3396	0	0	0
dimuon-5-hft	17138	44	17250	47	50	8 %	17138	17138	0	0
UPC-main-p	7343	28	7363	22	161	14 %	6038	6038	1305	0
Zero-bias	1802	7	1812	5	5	0 %	1802	1802	0	0
Zero-bias-pastprotect	1502	6	1511	4	4	0 %	1502	1502	0	0
Zero-bias-futureprotect	1802	7	1812	5	5	0 %	1462	1462	340	0
future-guardian	0	0	169000	0	4259	90 %	0	0	0	0
ALL	533371	1525	533758	1515	9383161	0 %	403154	227527	128343	8

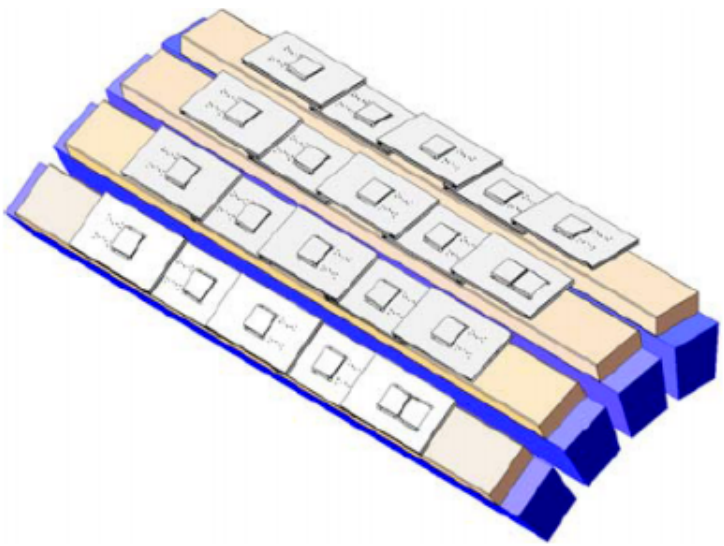
Det	State	Dead	CPU%	Evts	Hz	kB/s	Err
TOF	RUNNING	8 %	15	529741	1516	16667	0
BTOW	RUNNING	3 %	15	530259	1506	14745	0
Trigger	RUNNING	0 %	0	533758	1515	6764	0
ETOW	RUNNING	3 %	14	529963	1516	3187	0
BSMD	RUNNING	2 %	15	34584	93	1211	0
ESMD	RUNNING	4 %	51	529858	1513	28074	0
TPX	RUNNING	10 %	48	530199	1524	887216	8
PXL	RUNNING	4 %	16	369836	1096	102671	0
MTD	RUNNING	3 %	13	529356	1497	1314	0
IST	RUNNING	5 %	64	370394	1044	23710	0
SST	RUNNING	1 %	13	3089	8	5336	0
GMT	RUNNING	0 %	13	13715	37	911	0
L4	RUNNING	0 %	63	-1/291404	888	595179	0

Evb	State	Built	Err	Hz	MB/s	Written	Free GB	RCF W+S
evb01	RUNNING	44750	0	148	123	0 GB	6397 [87%]	148+10
evb02	RUNNING	35088	0	87	72.5	0 GB	6868 [93%]	17+13
evb03	RUNNING	49672	0	174	141.5	0 GB	6786 [92%]	37+20
evb04	RUNNING	49732	0	140	117.9	0 GB	6773 [92%]	41+15
evb05	RUNNING	47525	0	165	143.4	0 GB	6828 [93%]	25+20
evb06	RUNNING	49829	0	199	153.2	0 GB	6479 [88%]	115+17
evb07	RUNNING	49725	0	170	131	0 GB	10327 [93%]	21+21
evb08	RUNNING	49783	0	154	108.4	0 GB	10326 [93%]	21+15
evb09	RUNNING	49792	0	189	160.8	0 GB	10318 [93%]	23+23
evb10	RUNNING	49700	0	116	120.5	0 GB	9634 [93%]	25+17
ALL		475596	0	1542	1272.2	0 GB	80736 [92%]	473+171

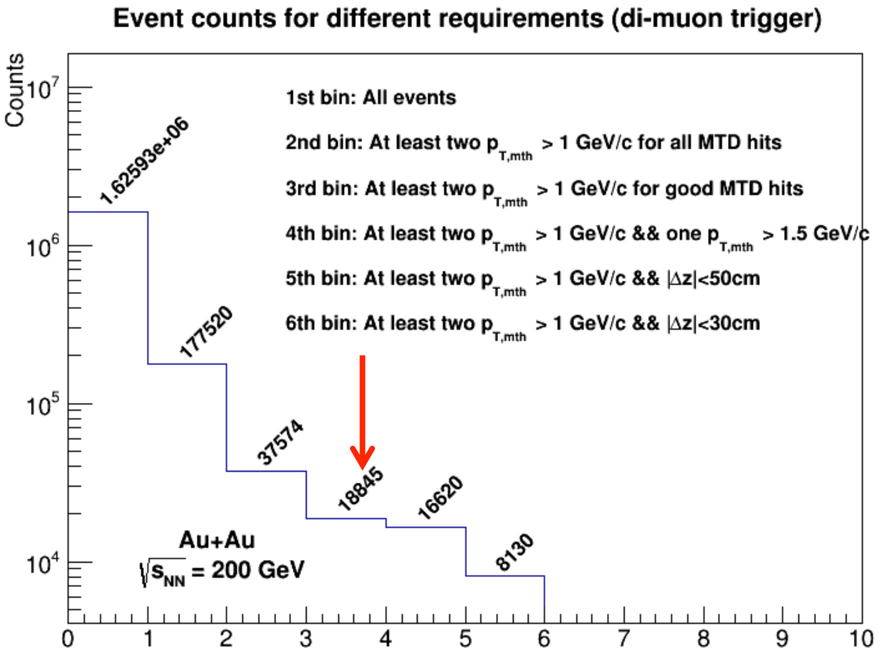
- STAR HLT can now handle ~1500Hz MB equivalent (with pileup protection)

Future Development: integrate MTD



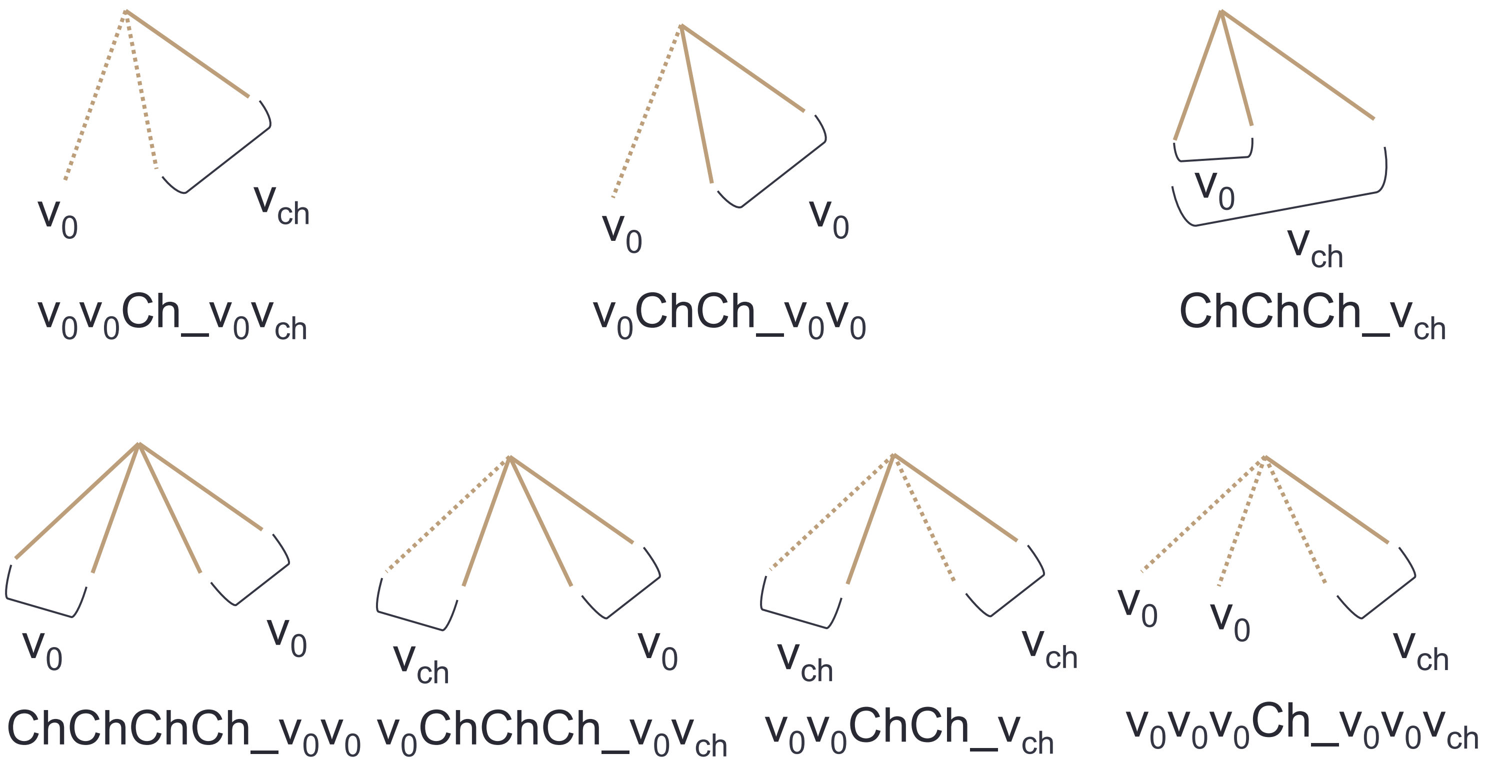


- Muon Telescope Detector is one of the two new detectors of this year.
- A significant fraction of di-muon triggered events are from background. HLT can help to make further rejections, thus reduce the rate to tape.



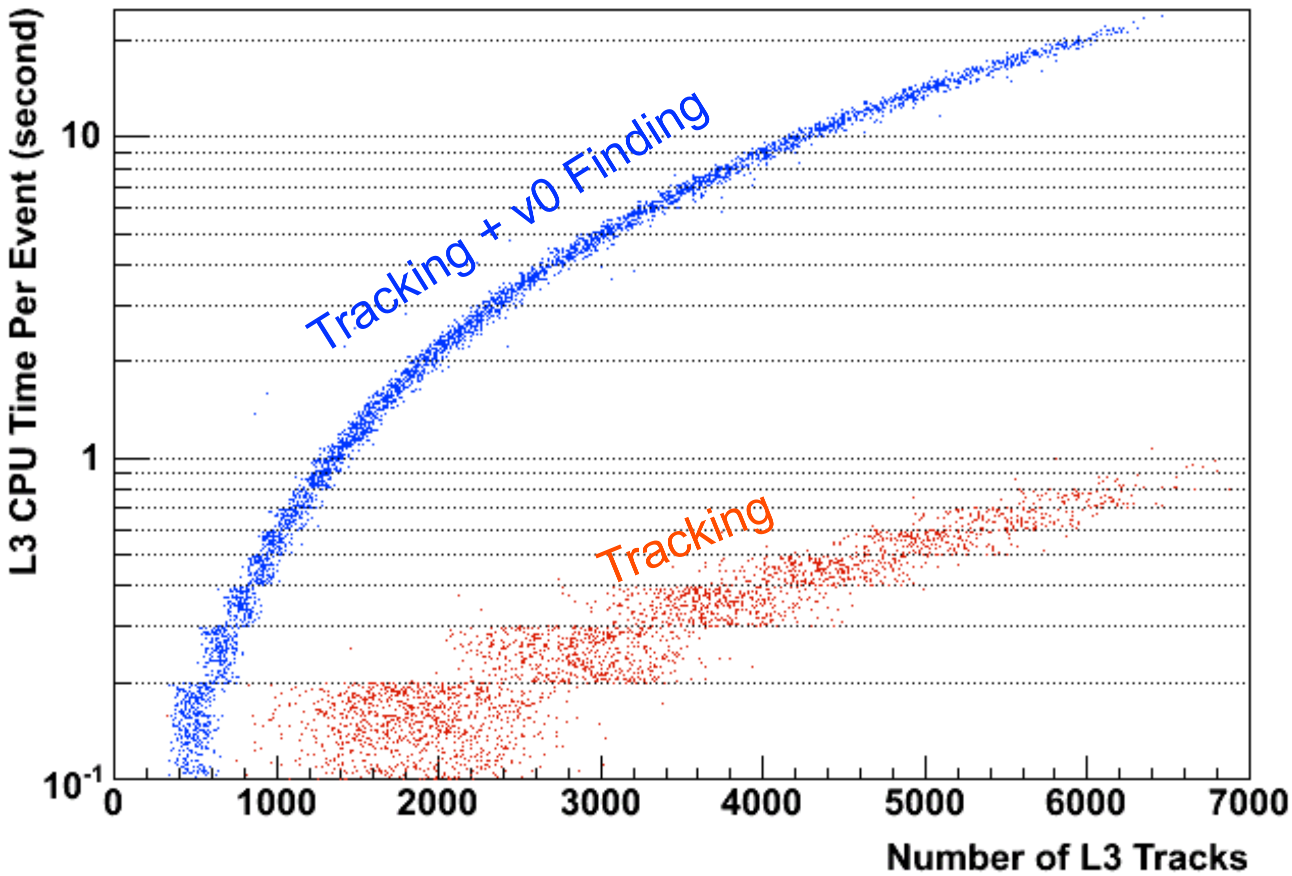
Future Development: V0 finding (1)

- Triggering secondary vertices online



Good potential for new discoveries (Strangelets, di-Ω etc.)
In the future we will upgrade HLT farm to trigger on secondary vertices.

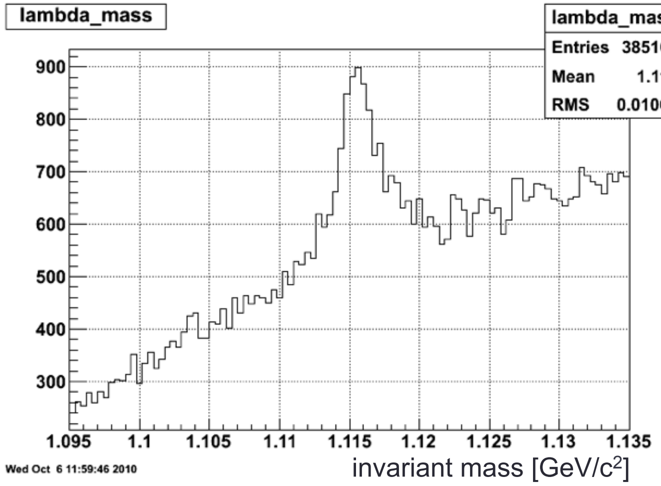
Future Development: V0 finding (2)



v_0 reconstruction is CPU intensive (~M^2).

Future Development: V0 finding (3)

- GPU accelerated V0 finder
  - DCA calculation offload to GPU
  - GTX280 VS 2.8CPU
  - 60x speed up, GPU + optimization

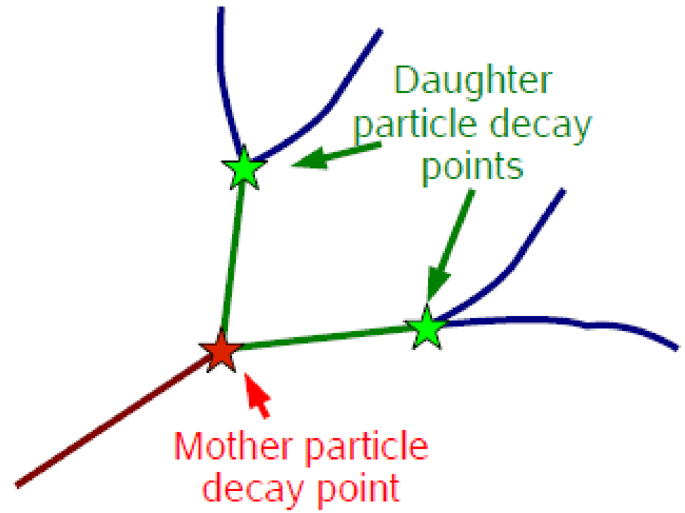


- Λ reconstructed by GPU
- Run10 Au+Au 200GeV
- HLT tracks

GPU significantly accelerates v_0 reconstruction.
A useful test but lack of manpower for further developments.

Future Development: : V0 finding (4)

- KFParticle on Intel Xeon Phi (pioneered by FIAS group)
- Intel Xeon Phi
  - 61 core
  - 4 hardware threads per core
  - 8G RAM
- How to fit our problem in?
  - A STAR HLT process uses ~250MB memory
  - Simple event level parallelization will not work
  - offload mode: offload secondary vertex finding to Phi, synchronization?
  - native mode: run the whole process on phi with multi-thread



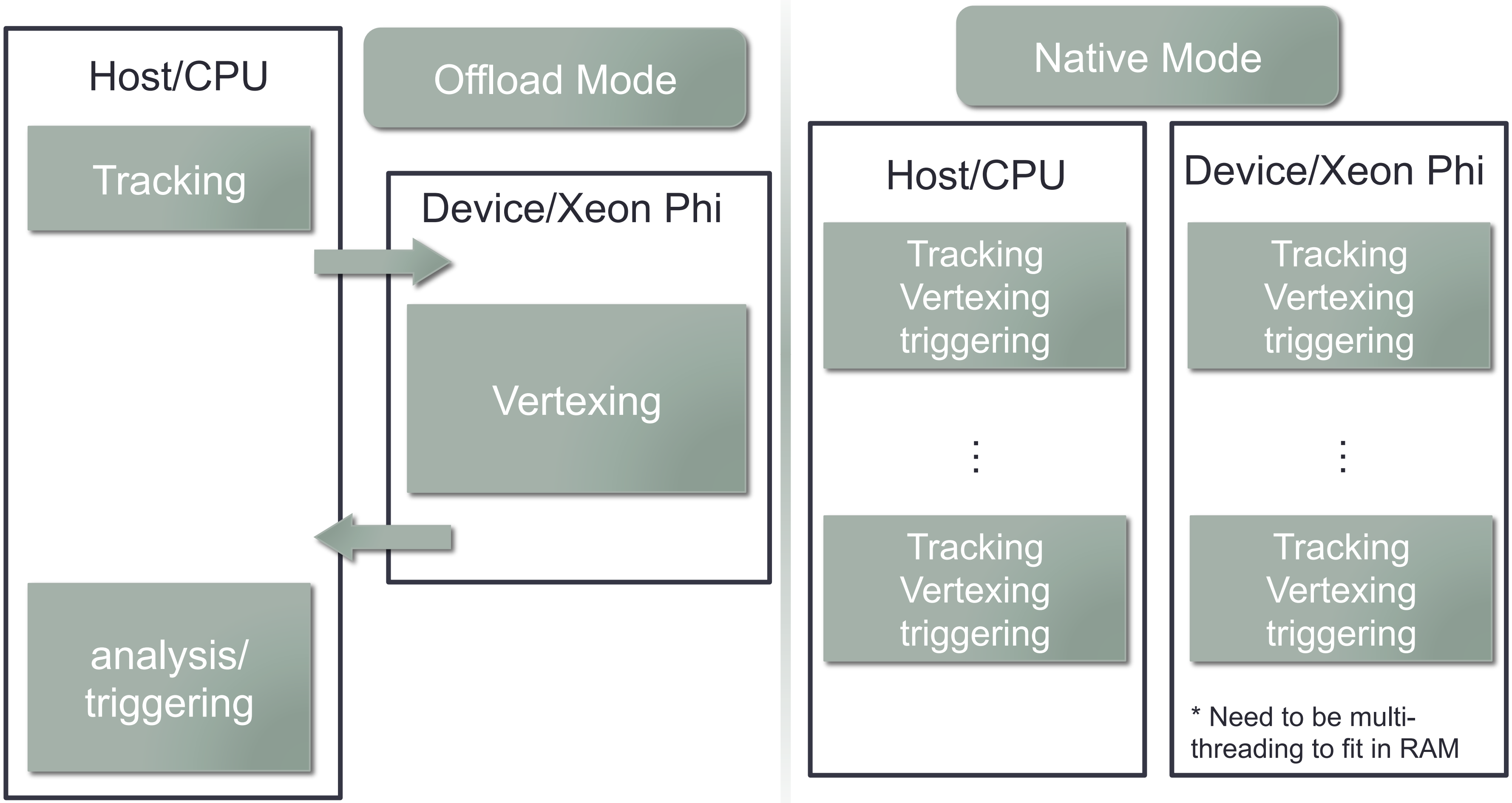
State vector

Position, direction and momentum

$\mathbf{r} = \{ x, y, z, p_x, p_y, p_z, E \}$

Future Development: using Xeon Phi

- Possible execute modes of using Xeon Phi in HLT (for discussion)



Summary

- It is demonstrated that we can deliver important physics fast with the HLT
- STAR HLT has successfully selected events of interests and sent them to express streams.
- STAR HLT can provide live feedback for collider steering and run progress monitoring
- New detectors will be included in HLT
- Triggering on online secondary vertices with Intel Xeon Phi is under development