Accelerator Physics EXperiment
Highlight of RUN 14

RHIC Retreat 2014

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Outline

- Goal
  - Improve machine performance
  - Support developments for RHIC future
  - Support beam instrumentation development
  - Inter-lab collaboration
  - Enrich accelerator physics knowledge
- Statistics
- Highlights
- Summary of RUN 14 APEX

RUN 14 Focus @ APEX workshop

- Heavy ion program
  - New lattice options for further improvement luminocity via
    - Beta* squeeze below 0.5m to accommodate the emittance reduction from Stochastic cooling
  - E-lens commissioning
  - Preparation for pA program
    - DX aperture scan
    - Au beam lifetime at proton injection energy
- Injector chain
  - He-3 accelerating
- DX shift for preparation of asymmetric collision operation

APEX Statics

RUN	Scheduled/Planned[%]	Beam Availability [%]
RUN-3	80	65
RUN-4	90	84
RUN-5	84	83
RUN-6	89	86
RUN-7	92	72 (physics: 49%)
RUN-8	97	83.4 (physics: 59%)
RUN-9	98	82.9 (physics: 54%)
RUN-10	79	82.5 (physics: 83%)
RUN-11:pp	42	92 (physics: 37%)
RUN-11:Au	63	78.5 (physics: 59%)
RUN-12:pp	134	86.8
RUN-12:ion	61	93.7

- Run-11 APEX average availability: ~82%(ops certified accounting)
- lower ratio of Scheduled/Planned was due to the poor machine availability

APEX Statics

RUN	Scheduled/Planned[%]	Beam Availability [%]
RUN-6	89	86
RUN-7	92	72 (physics: 49%)
RUN-8	97	83.4 (physics: 59%)
RUN-9	98	82.9 (physics: 54%)
RUN-10	79	82.5 (physics: 83%)
RUN-11:pp	42	92 (physics: 37%)
RUN-11:Au	63	78.5 (physics: 59%)
RUN-12	100	83.3
RUN-13	78	86.6
RUN-14:Au	100	79.9
RUN-14:He3Au	100	88.1

- Data collected from Peter Ingrassia

Studies Proposed for RUN14

Study #	title	Studiers	priority	Total time [h]
14.2	DA measurement w. 2.5GeV working point	Montag	1B	4
14.9 14.7	DX aperture scan & effect of H offset in triplets	Luo, Marusic, Tepikian, Bai	0A 1A	11
11-33	IP coupling matrix measurement	Tepikian	0A	7
14.16	Ramp optics	Liu	0A	6
14.10	Momentum aperture scan	Luo	0A	4.5
14.6	Elens and Ion beam	Gu, Fischer, Luo, White	1A	24
N/A	Telescope Beta squeeze	GRD, Marusic, Bai	N/A	7.5
14.8	RHIC longitudinal impedance measurement	Blaskiewicz	1A	4.5
14.4	Measurement of total AuAu cross-section	Fischer	2A	2
14.3	S* knob S* correction for He3Au	Bai, Hao, GRD, Duan, Shen	0A	7 2

Studies Proposed for RUN14

Study #	title	Studiers	priority	Total time [h]
14.5	Non-linear driving term	Jing	0A	7
14.14	Polarimeter target light observation	Huang	0A	2
14.13	Beam-beam driven non-linear resonances and amplitude detuning measurement	White	1B	5
12-22	Head-tail chromaticity measurement	Ranjbar	0A	2
	Asymmetric beam beam study	Luo		5
	Au ramp and store just above transition	Montag		3.5
	Spin flipper AC dipole bump closure	Oddo		1
	Injection tuning	Liu		1
14.12	Off-momentum optics as a function of phase advance between low-beta insertions	White	1A	0
14.11	Near-integer Beam Dynamics Study	Luo, Bai	2B	0
14.1	2.5GeV Au beam in RHIC	Montag	1A	0

Elens Commissioning

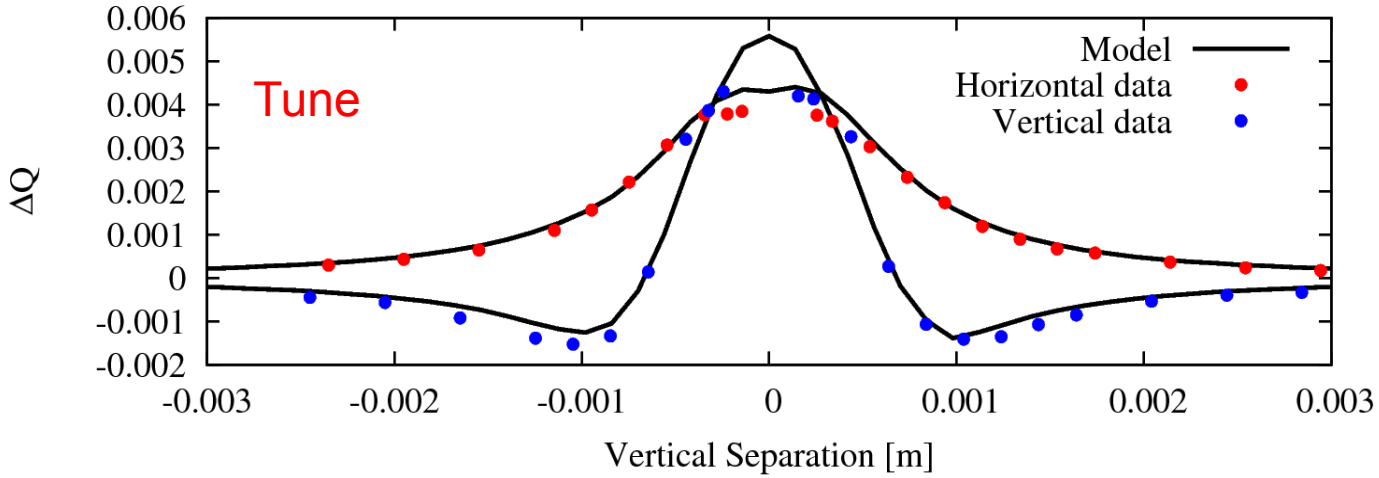
- Plan to
  - exercise transverse alignment of e beam w Au beam
  - Measure the impact of e-Au on beam emittance as well as beam lifetime
    - The SC cooled Au beam allows for reversal of emittance growth
  - Observe beam-beam driven instabilities

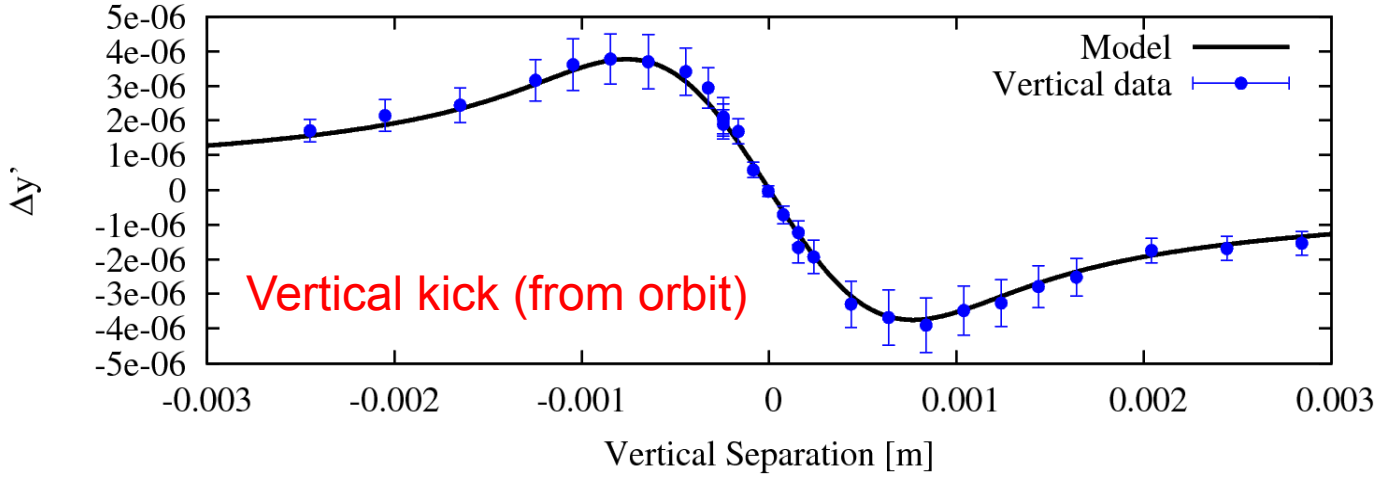
	Au+Au 2014	p+p 2015 (100 GeV)
Beam loss	~8 %/hour burn-off dominated	~3 %/hour beam-beam dominated
Emittance growth	negative IBS + stoch. cooling	positive beam-beam
Max beam-beam param. x	0.006 / IP	0.012 / IP
$s_{e\text{-beam}} / s_{p\text{-beam}}$	≈ 2	≈ 1

Courtesy of W. Fischer

Elens Commissioning

- Effect of e-beam on Au beam's orbit and tune was measured and used as 1st alignment tool

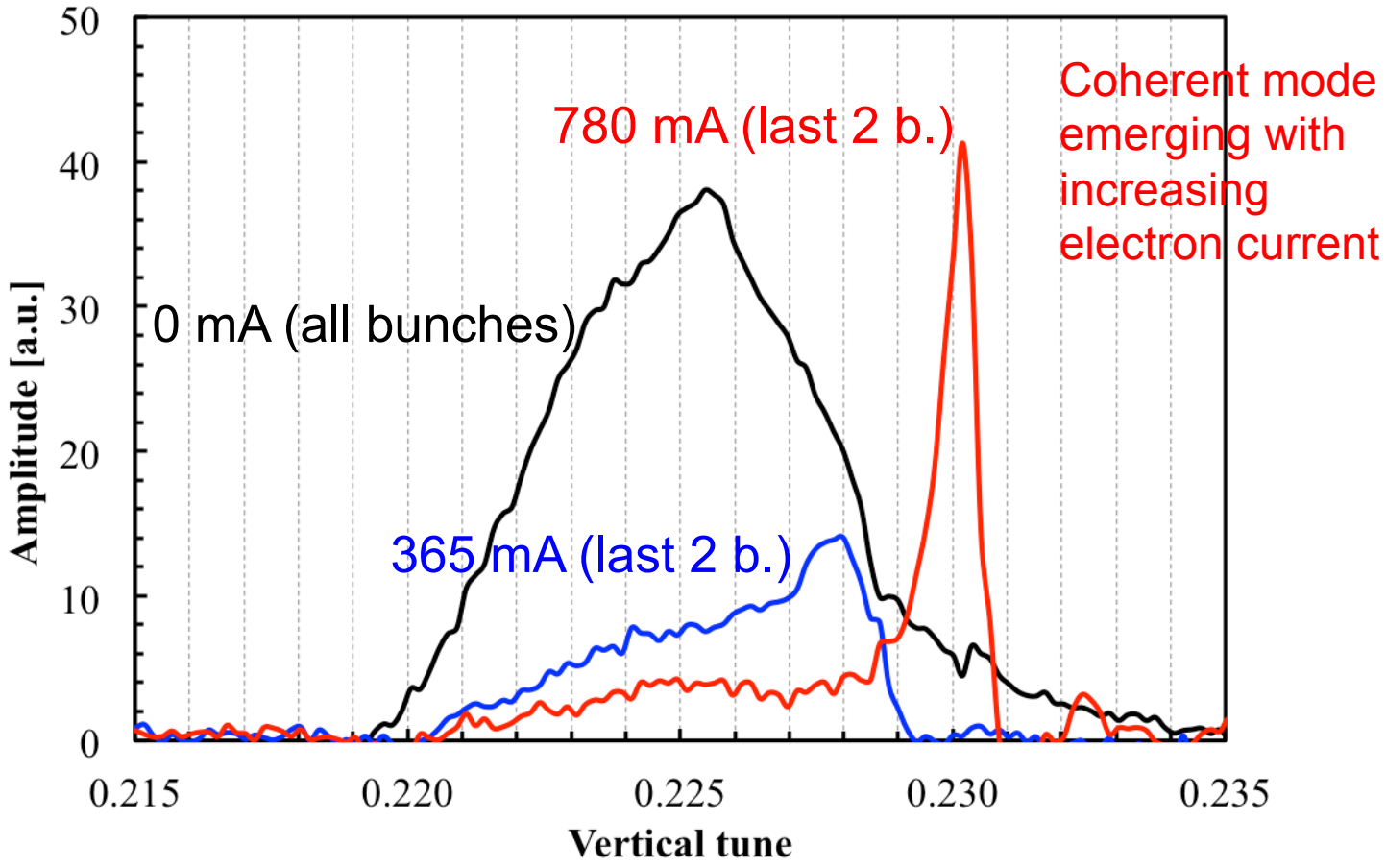




Courtesy of W. Fischer

Elens Commissioning

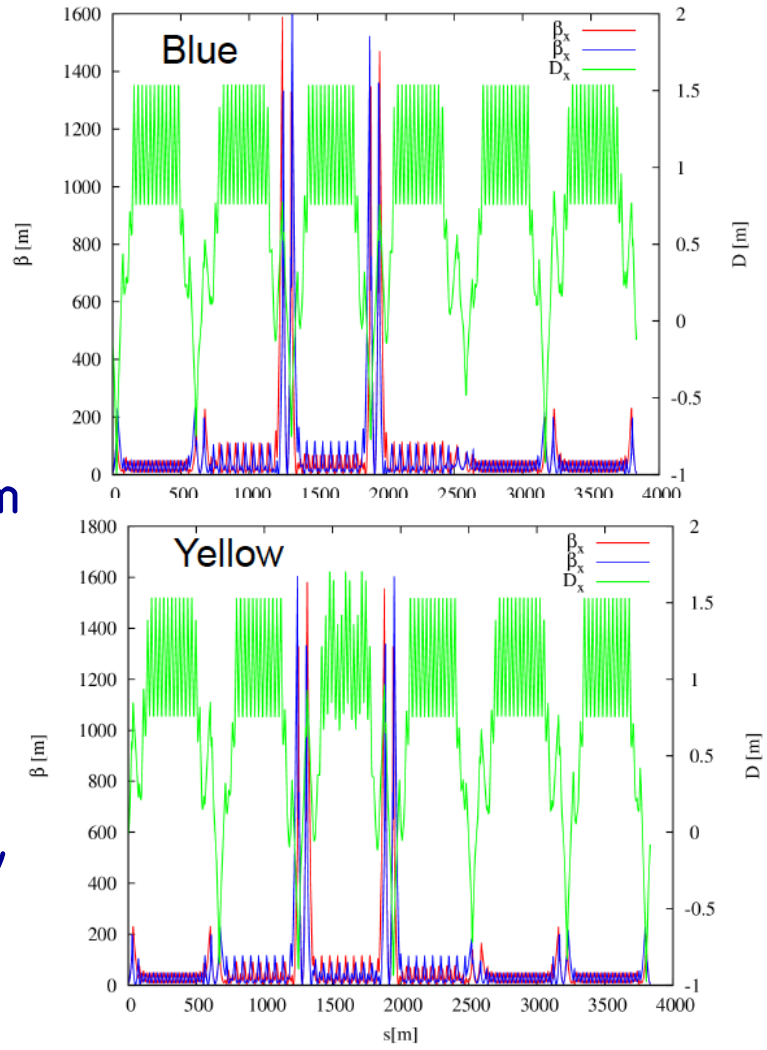
- Vertical BTF measurement with e-beam during Physics store shows reduction of the incoherent tune spread and also the emergence of coherent mode at higher e beam current



Courtesy of W. Fischer

Elens Plan for coming pp RUN

- Large cathodes
  - allows for matched beam size w. high solenoid field
  - Raises instability threshold
  - Easier alignment
- Transverse damper
  - Bunch by bunch to fight beam-beam driven instabilities if needed
- New lattice using ATS optics
  - Phase advance between IP6/8 and IP10 is $k\pi$
  - Minimize the nonlinear chromaticity
  - Polarization transparent



Courtesy of W. Fischer

DA Measurement with 2.5 GeV working point

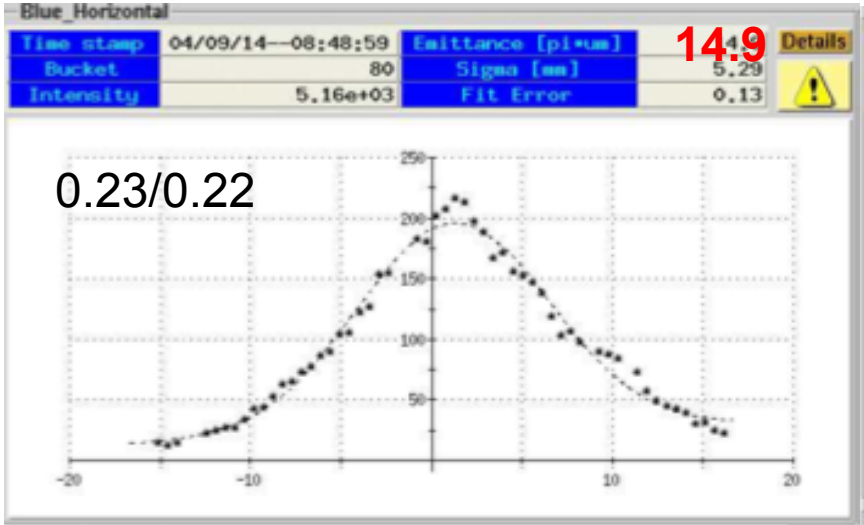
APEX

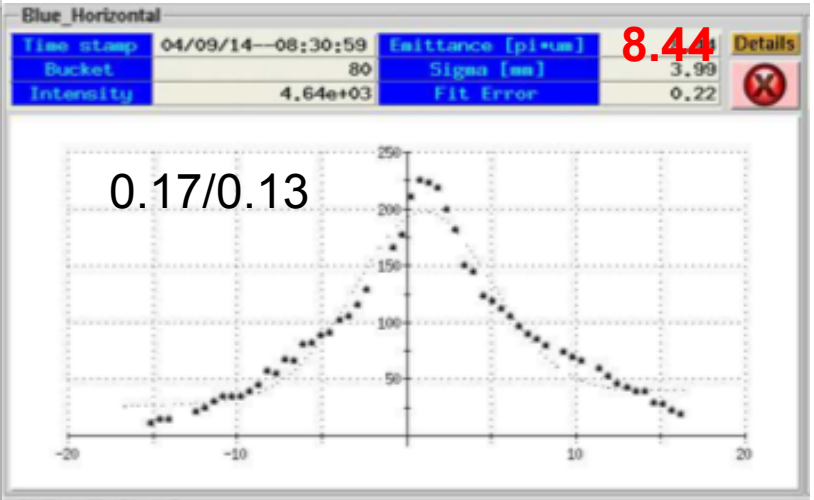
- Goal is to understand the surprisingly small DA at 5.86 GeV(proton beam), for which working point was set to 0.17/0.13
- Measure DA at Au regular injection energy with several different working points
- Data is affected by various issues
  - Blown up beam due to AtR quadrupole problem
  - Non-gaussian beam profile
- Nevertheless, qualitatively the measurement confirmed that DA aperture at tune of 0.17/0.13 is worse than all other choices, especially 0.13/0.12, which had been used at other low energy runs

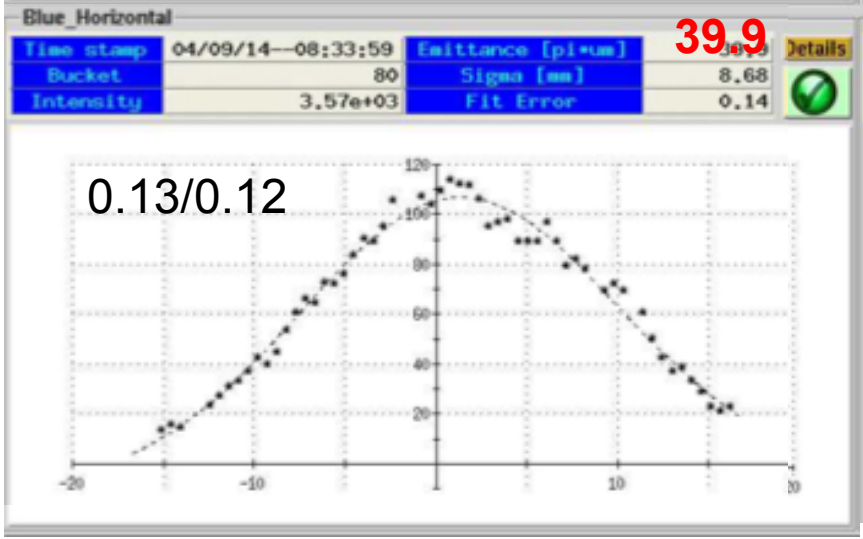
DA Measurement with 2.5 GeV working point

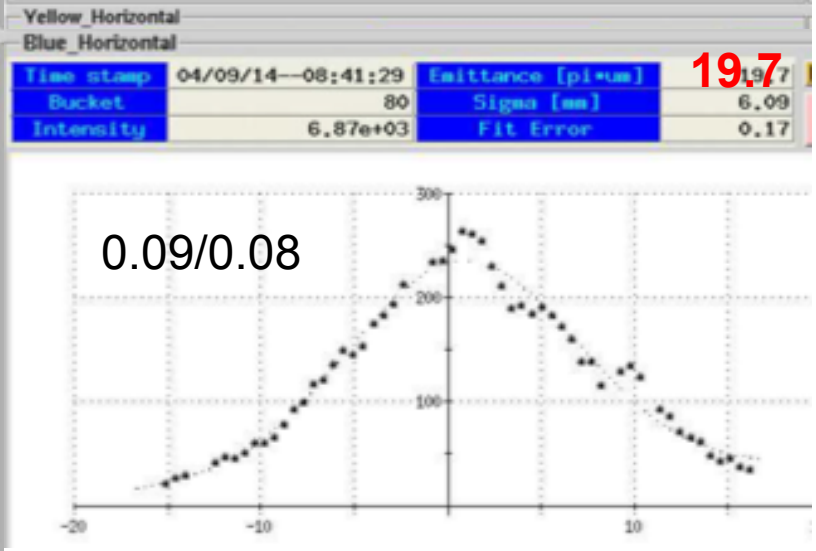
APEX

- DA scan (only showing Blue data)







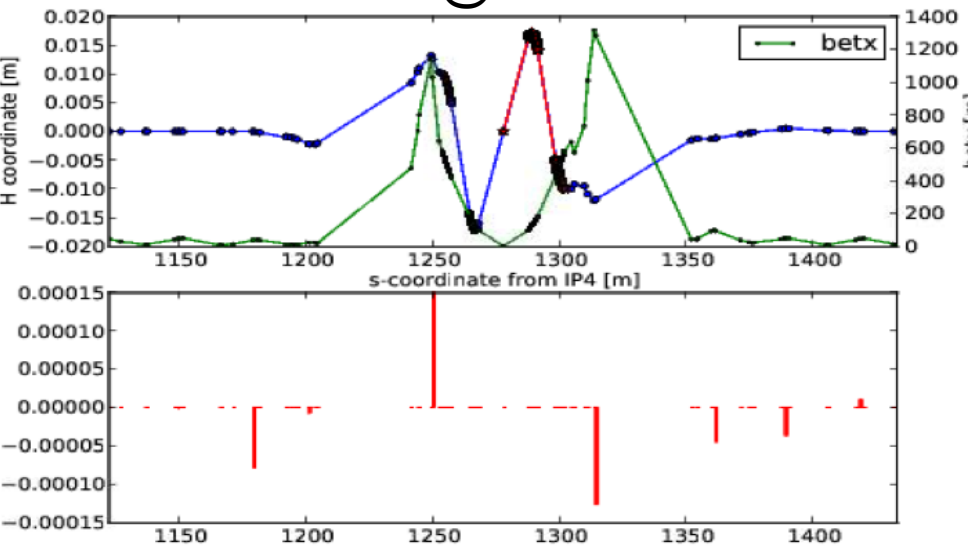


DX Aperture Scan

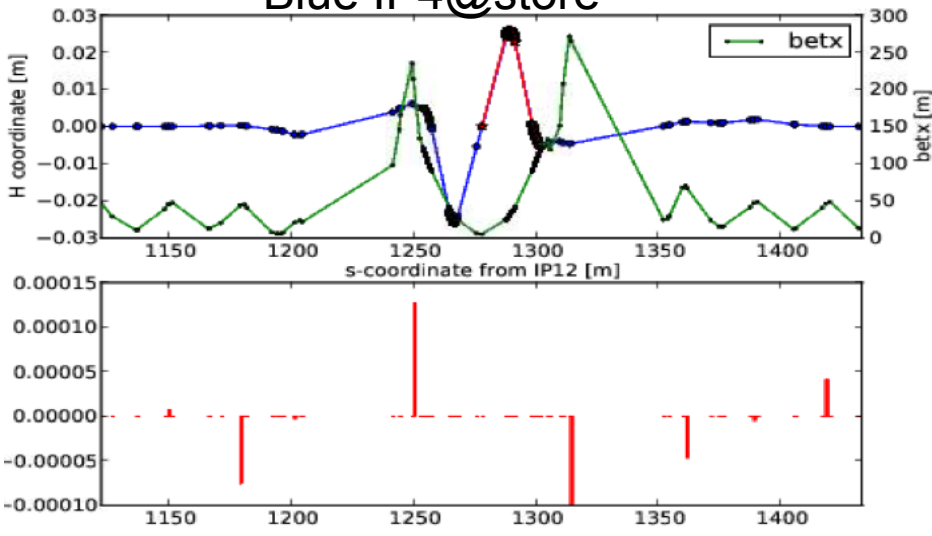
APEX

- Confirm the DX aperture scan in RUN13
- Exercise the Triplet aperture scan at injection and store

Blue IP8@store



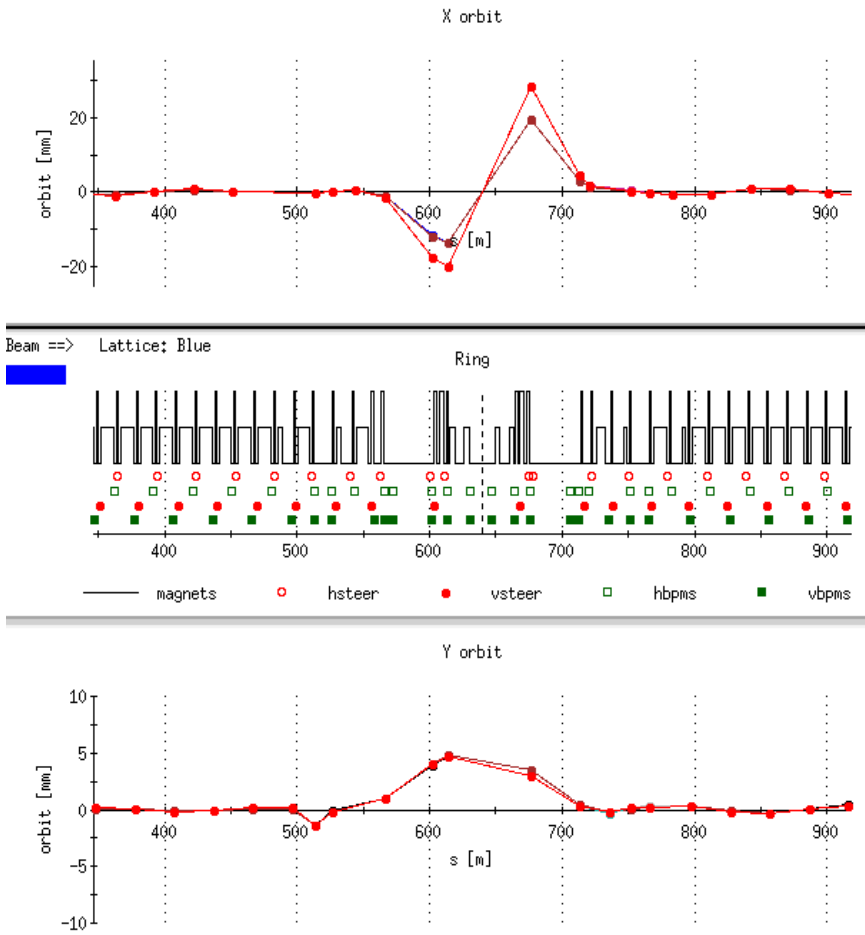
Blue IP4@store



DX Aperture Scan

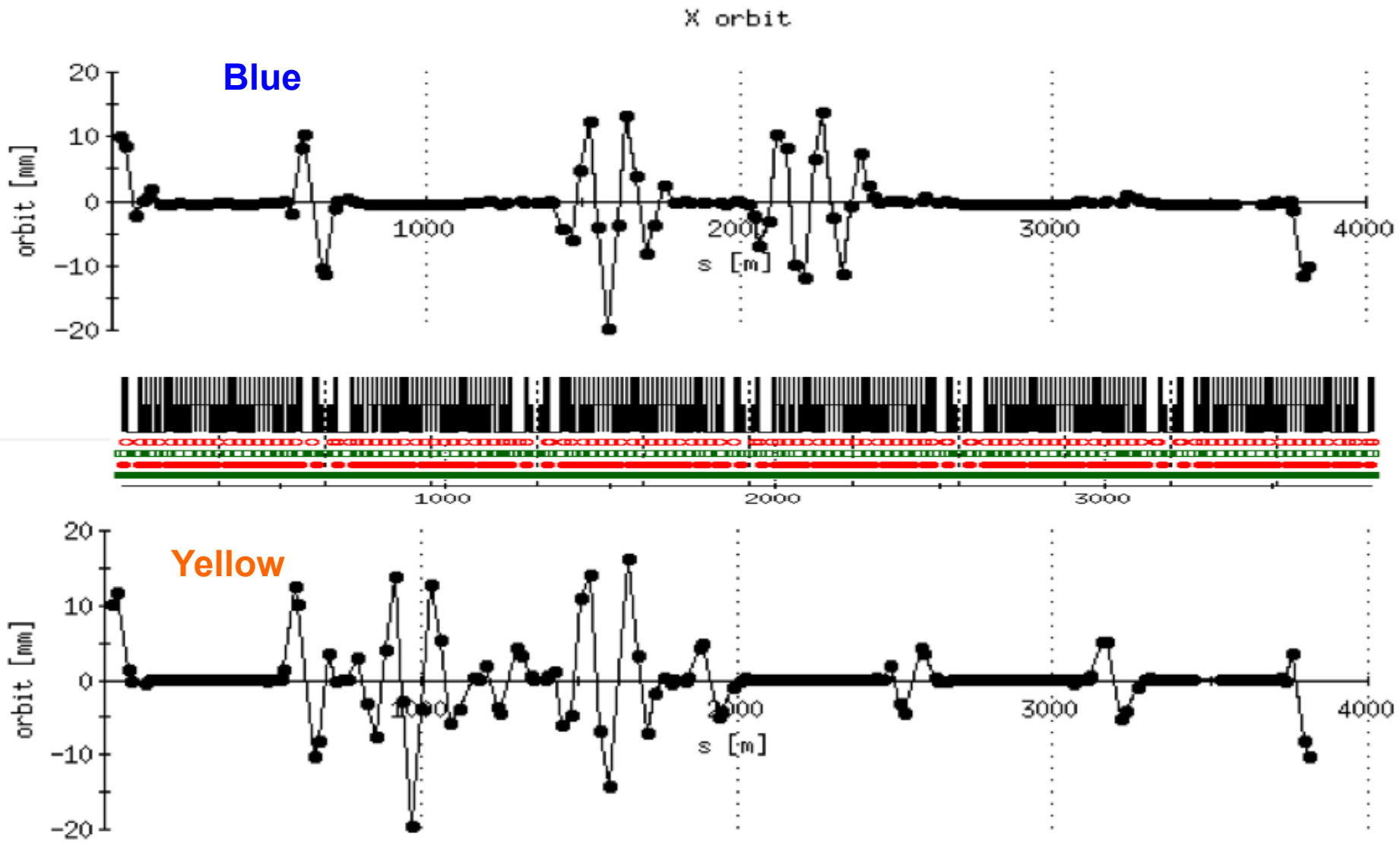
APEX

- Confirmed the DX aperture scan in RUN13
- Exercised the Triplet aperture scan at injection and store
  - Critical in developing as well as debugging the Ramp Manager and WFG Manager to accommodate un-equal species collisions
  - Confirmed a 15mm offset in triplet has negligible effect on beam lifetime for the He3Au lattice in RUN13

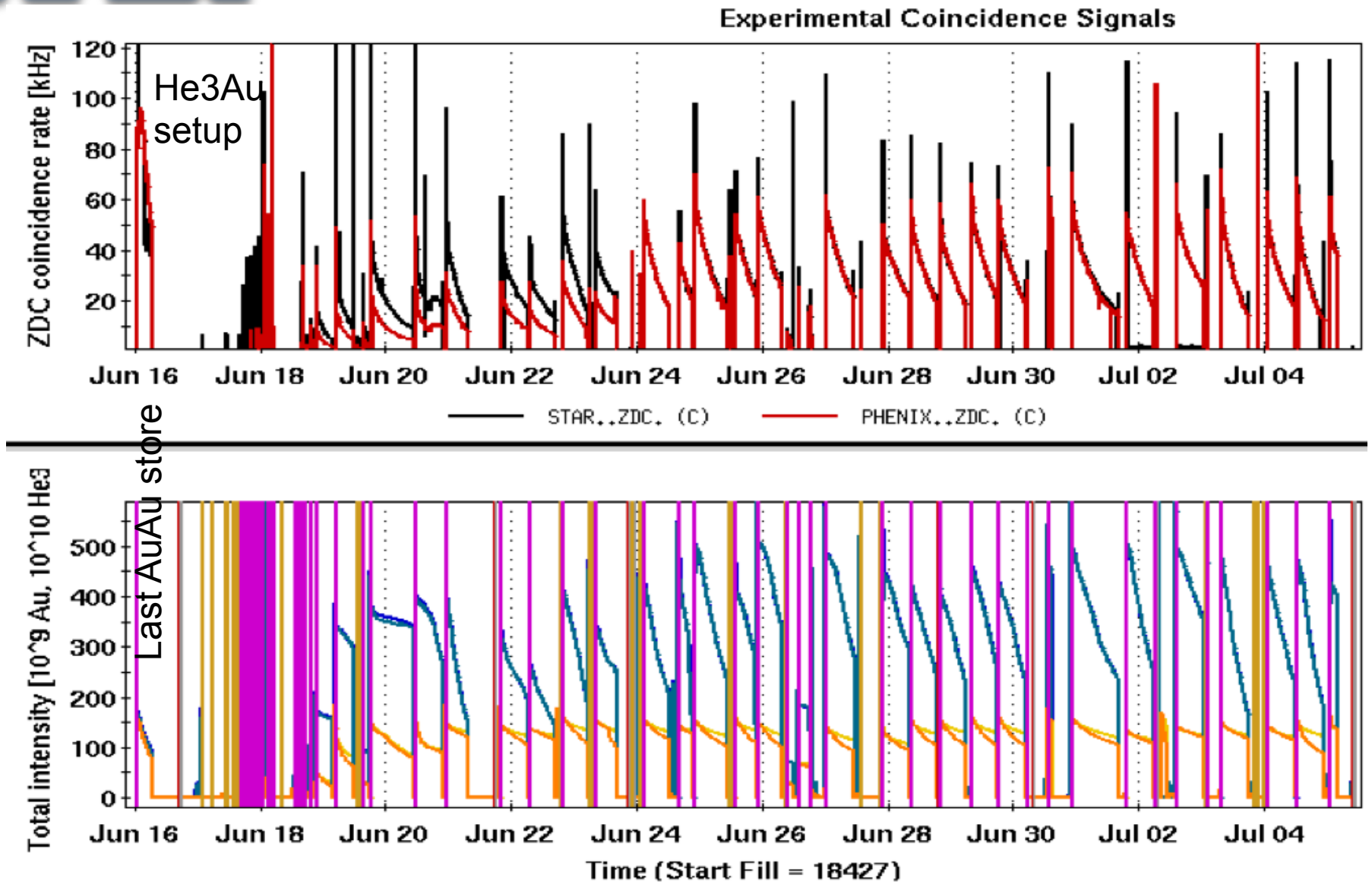


He3Au Orbit@Store

APEX



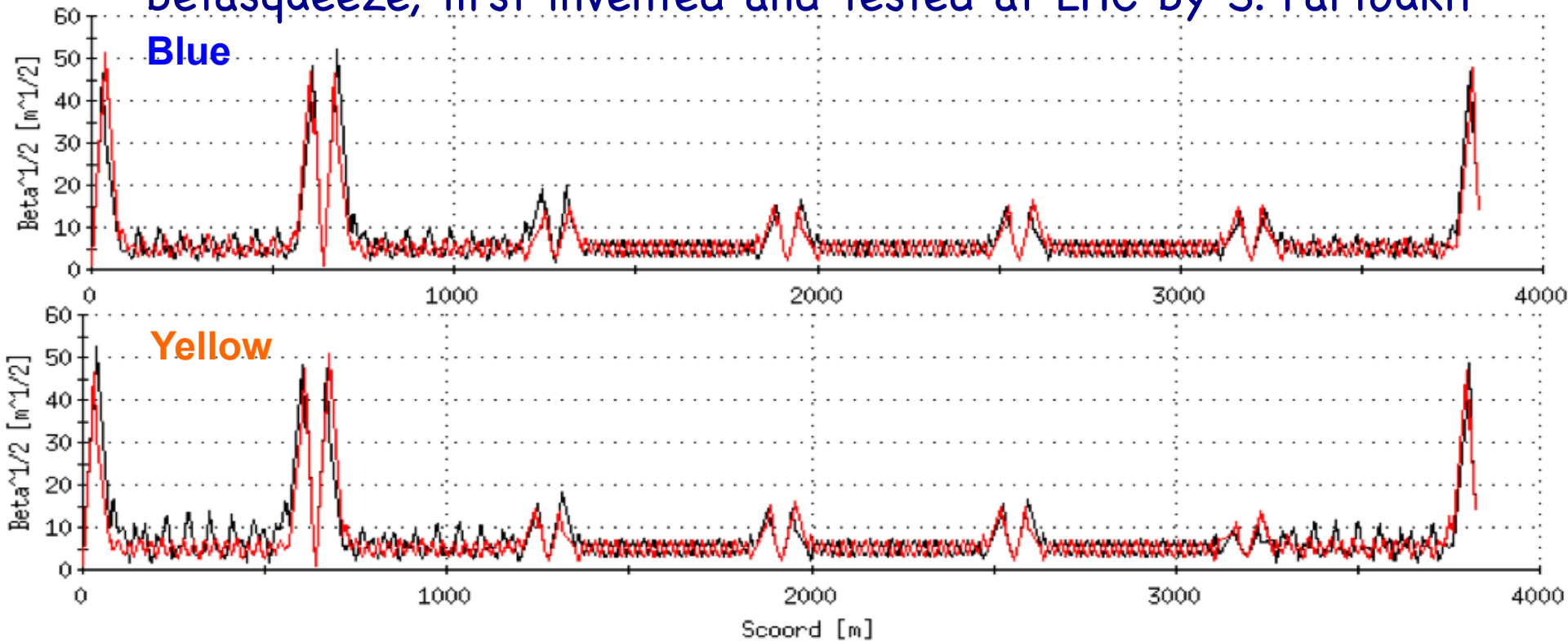
He3Au Run


Experimental Coincidence Signals
ZDC coincidence rate [kHz]
120
100
80
60
40
20
He3Au
setup
Jun 16
Jun 18
Jun 20
Jun 22
Jun 24
Jun 26
Jun 28
Jun 30
Jul 02
Jul 04
STAR..ZDC. (C)
PHENIX..ZDC. (C)
Last AuAu store
Total intensity [10^9 Au, 10^10 He3
500
400
300
200
100
0
Time (Start Fill = 18427)

Telescope beta squeeze development

APEX

- SC opens up the possibility of lumi leveraging by further squeeze beta* during a physics store
- Launch large beta-beat in the arcs to reach beta* of 0.5 m
- This technique was inspired by the Achromatic Telescopic betasqueeze, first invented and tested at LHC by S. Fartoukh



Telescope beta squeeze development

APEX

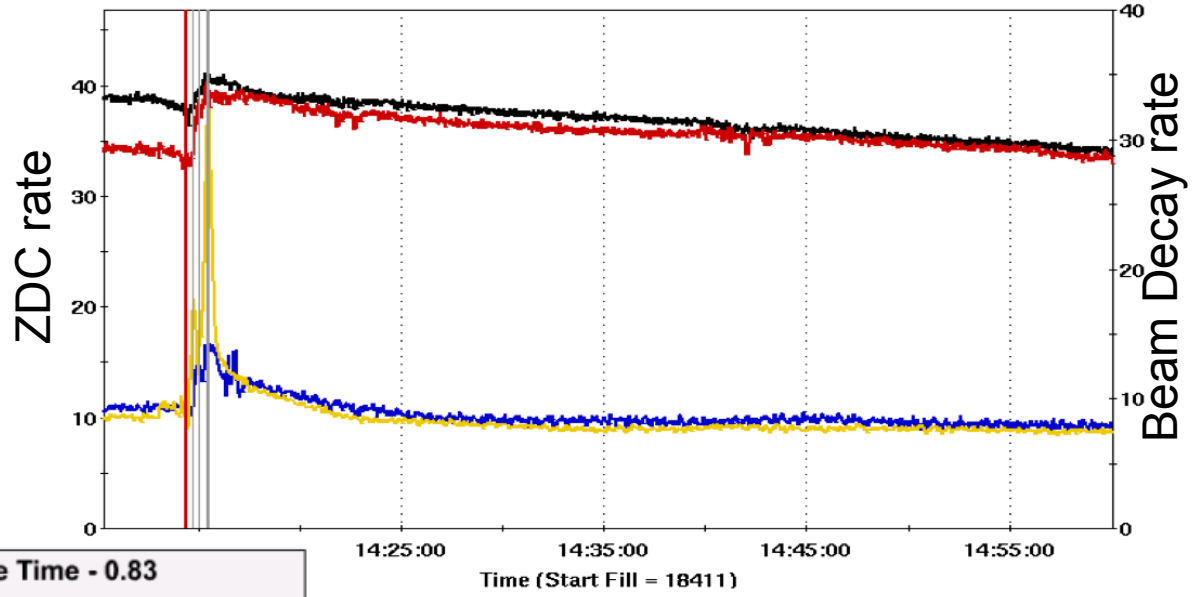
- **APEX attempt**
  - First APEX attempt: Fill #18126
    - Established the storage ramp for telescope beta squeezing to 0.6m beta*
    - 1st time 100% online betabeat correction with loptics
  - first time reaching 50cm in Blue for Fill #18128
  - first time with 50cm in Yellow for Fill #18239
- **End of store experiment:**
  - with a 12x12 test ramp (APEX) = Fill #18272
  - with a full 111x111 = failed (LISA used Au14-s0 to re-optimize), Fill #18261
  - with a full 111x111 = successful, Fill #18320 (both Blue and Yellow)
- **THOR declared operational at Fill 18413 (6/12/2014)**

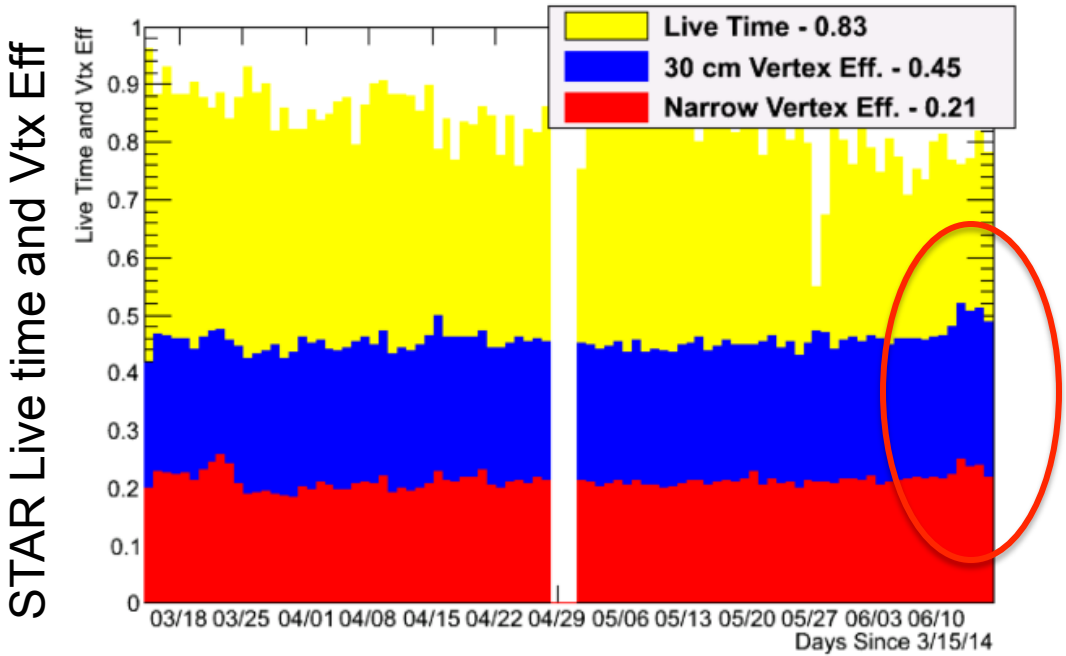
From GRD

Telescope beta squeeze

APEX

Direct benefit of success of THOR lattice





After THOR was operational and implemented at 7 hour into a physics store

Summary

- RUN 14 APEX program has been very fruitful. A handful of beam studies directly benefited the RUN14 performances in luminosity as well as versatility
- The past decadal experience of APEX has shown that APEX is one of the crucial investment to ensure the continuous performance improvement of RHIC as well as future projects
  - CeC PoP, low energy operations, etc
- **APEX HAS NOT been and WILL NEVER be the Stumbling Block of RHIC!!!**