The APEX Program at BNL

Fulvia Pilat

Tevatron Accelerator Studies Workshop

FNAL, January 13-14, 2010

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APEX Program Goals

- Improvement of RHIC operational performance
- Experimental activity to support RHIC future program (cooling, eRHIC, low energy RHIC…)
- Collaboration with other institutions (CERN,FNAL, NSLS- II…)
- Support general understanding of accelerator physics
- Development of diagnostics and operational techniques

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APEX Program implementation

- Started in RHIC Run-1 (2001-012) and evolved progressively

- **weekly program** discussed and approved on Fridays, scheduling confirmed at the Monday (weekly) scheduling meeting
- 12 hours of beam time/week regularly scheduled on Wednesdays during the physics running periods

- **1 Workshop/year** prior to (4-6 weeks) the beginning of the RHIC
- **Proposals** are submitted via a WEB interface (with special provisions for authorization of studies with planned beam loss)
- Proposals are **reviewed and prioritized** by a standing departmental committee (AEAC, Accelerator Experiments Acceptance Committee)
- Program and scheduling are managed by the APEX Coordinator

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Accelerator Experiments Acceptance Committee

date: September 22, 2009

to: Collider-Accelerator Department Personnel

from: D.I. Lowenstein

subject: **FY 2010 Collider-Accelerator Department Committees**

V. Litvinenko, Chair
M. Bai
W. Fischer
H. Huang
D. Lowenstein
F. Pilat
P. Pile
T. Roser
S. Vigdor, ALD
P. Yamin

- The Committee meets a few times per year to review and to classify the proposals
- It decides on APEX **priorities** on the basis of agreed selection criteria
- The committee accepts, rejects and evaluate the proposals based on their **scientific merit** and **relevance** to present and future of the RHIC program
- The goal is to provide **fair evaluation** and classification of the proposals
- The committee evaluations assign priorities for scheduling.

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Evaluation criteria

a) **Relevance to RHIC performance and operation**
b) **Scientific merit**
c) **Level of preparedness**

Grading

0 Likely to immediately benefit RHIC machine performance, or crucial to RHIC hardware decision-making
1 Directly benefiting RHIC machine performance in the future
2 Accelerator physics in general

A – must do
B – recommended
C – considered for inclusion
D - declined

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Examples of most successful studies

- Stochastic cooling – initially was developed as part of the APEX, now is the baseline luminosity upgrade for RHIC II
- Reduction of β* - feasibility of smaller beta* established for years in APEX, resulting in significant increases in luminosity (see later)
- Tune and decoupling feed-back – implemented now in operations, dramatically reduced time for developing of new ramps
- IBS suppression lattice - had been implemented into operations, provided for reduction of IBS emittance growth

- Many more - resulted in higher luminosity, better modes of operation and, finally, in better understanding of RHIC and accelerator physics

APEX operations statistics

Run	Scheduled/Planned %	Beam/scheduled % (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-9 APEX average availability: 83% (ops accounting)
Run-9 Operations time at store : 54%

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Run-9 overview

http://www.c-ad.bnl.gov/APEX/APEX2009/

APEX Sessions	APEX elogs	APEX Results
March 17-18 2009	Elog1 Elog2	Summary Polarimeter-study
March 25 2009	Elog1	Summary Polarimeter-study DX-D0-study
March 31 – April 1 2009	Elog1 Elog2 Elog3	Summary IR-corrections Spin-tune-study
April 8 2009	Elog1	Summary
Overall apex PLAN for the 100 GeV run		
April 28-29	Elog1 Elog2	Polarimeter-study DA PS-Beam-Noise Beam-Beam-Wires
May 4 2009	Elog	Summary DX-D0
May 12-13	Elog1 Elog2	Summary Space-charge-Beam-beam Bunch-length-limit Off-mom-beta-beat Long-range-beam-beam
May 20 2009	Elog	Summary Off-momentum-beta-beat
May 26-27 2009	Elog1 Elog2	Summary Nonlinear-chrom Long-range-Beam-beam DX-D0 Impedance Linear-optics-correction Polarimeter-studies pp94-ramp-test
June 4 2009	Elog	
June 9-10 2009	Elog	Summary
June 16 2009	Elog	Summary
June 23-24 2009	Elog	Summary
End-of-run-studies July 4=5	Elog	Summary

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12 sessions of APEX in Run-8

APEX Run-9: studies with 250 and 100GeV PP

Operations		ORM
Operations		Nonlinear chromaticity
Operations		IR nonlinear corrections
08-29 08-10	0A	Polarimeter studies
09-10	0A	BTF – BBQ calibration
08-27	0A	Beta measurements
Development		pp93lowbeta (at 250 GeV)
09-05	0A	Dx-D0 study
09-22	0A	Spin tune vs. orbit
08-17	0A	pp93low beta preparation and commissioning
09-26	0B	DA with AC dipole (injection)
07-19 07-20	0A	Noise PS
08-08	1A	Long range beam-beam
09-17	1A	Space charge an beam-beam
09-21	1A	Bunch length limit
09-06	1A	Off momentum beta-beat
08-27	0A	Linear optics corrections
Development		pp94nearInt commissioning
		Spin flippers

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APEX Schedule End of Run-9 July 4-5

pp94nearInt 250 GeV Ramp development Move Q closer to integer BBQ	Ramps 100 GeV BBQ	Store 100 GeV	Ramps 100 GeV	Injection
Development pp94nearInt Bai + Ptitsyn + team + operations	Yellow transmission Schoefer, Fischer operations	BBLR Fischer Calaga	Main PS Transient Schultheiss	Spin Flippers Bai, Roser

10am midnight 6am 9am noon 4pm

Store 100 GeV	Injection Store	Ramp+ store 100 GeV	Store 100 GeV	Store 100 GeV BBQ		
Spin Tune Bai Ptitsyn	Linear Optics Correction Wang Bai	Blow-up Emittance Schoefer	Beta* Measure Ptitsyn	IR Octupole Pilat Marr	Polarimeter Huang +team	

4pm 10pm midnight 2am 4am 7am 8am 10am

Plans for Run-10

- Studies with Au-Au
- Studies with Au in preparation for Run-11 (PP)
- Studies for and at low energy
- Studies in injectors (Au and PP)
- Studies towards future projects

Budget guess → 25 weeks cold operations (~15-20 weeks of physics)

Deadline December 5, 2009 for:

- Submission of new proposals
- Communication status and intentions for Run-8 and Run-9 study proposals

Meeting AEAC → week in December 29, 2009

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Proposals for Run-10

Exp. No.	Exp. Title	Spokesperson	Status	Species	Priority
09-05	D0DX optimization and DX BPM calibration	W. MacKay	Running		0A
09-06	Off Momentum Beta-Beat & Dispersion Measurement	R. Calaga	Running		1A
09-07	RHIC Transverse Impedance & Localization	R. Calaga	Proposed		1C
09-12	Tune Feedback with beams in collision: documenting available tune window	M. Minty	Completed		1A
09-13	Tune Feedback with beams in collision: maintaining optimum operating point	M. Minty	Running		2A
09-17	Interplay of space-charge and beam-beam effects	A. Fedotov	Running		1A
09-21	Study of bunch length limits	V.Ptitsyn	Running	P	1A
09-23	ATR Emittance – Quadrupole Scans	M. Minty	Running		1A
09-24	ATR Flags – Reference Images	M. Minty	Running		operations
09-26	Measure DA using AC dipole	M. Bai, F. Pilat	Running		0B
10-01	Pi-modes vs. betatron phase advance	C. Montag	Approved	split & re-submit	
10-02	Effect of long Gaussian tails on beam lifetime in the oncoming beam	C. Montag	Approved	pp?	1B
10-03	10 Hz Global Orbit Feedback	Rob Michnoff	Approved		0A
10-04	Electron lens straightness requirements	C. Montag	Approved		1C
10-05	Slow global orbit feedback, ramp	Minty	Approved		0A
10-06	Slow global orbit feedback, at store	Minty	Approved		0A
10-07	Dynamic beta squeeze	Guillaume Robert-Demolaize	Approved		0A
10-08	High Order Nonlinear IR Corrections	C. Zimmer	Approved		0A
10-09	RHIC Energy Limits	V.Ptitsyn	Approved		1A
10-10	Transition Single Bunch Instabilities	R. De Maria	Approved		1A
10-11	Development and evaluation of IBS suppression lattices	Vladimir N Litvinenko	Approved		1A
10-12	Development of lattice with 90-degrees phase advance for near 2/3 resonance operation	Vladimir N Litvinenko	Approved		1A
10-13	Gold charge state distributions at 17.5 MeV/u	Peter Thieberger	Approved		2A
10-14	Acceleration near 2/3 resonance	G. Marr	Approved		1A

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Beta* squeeze at RHIC

GOALS:

- Increase of **luminosity**
- Preparation for **dynamic beta* squeeze** with transverse stochastic cooling

HISTORY:

Run	Species	Energy (GeV/u)	$\beta^*(m)$ operations	$\beta^*(m)$ APEX
Run-1	Au - Au	65.2	3	
Run-2	Au - Au	100	1	
Run-3	d - Au	100	2	
	P - P	100	1	
Run-4	Au - Au	100	1	0.85
	P - P	100	1	
Run-5	Cu - Cu	100	0.85	
	P - P	100	1	
Run-6	P - P	100	1	
Run-7	Au - Au	100	0.8	0.65
Run-8	d - Au	100	1→0.7	0.7
	P - P	100	1	0.65
Run-9	P - P	250	0.7	0.5
	P - P	100	0.7	*0.5*
Run-10	Au-Au	100	0.6	*0.5*

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Beta* squeeze: methodology

- ***Before beam***
- the optics matching to lower β^* in IP6 and IP8 is turned into a **ramp** with ramp application software The ramp, typically 300 s, is first tested without beam for ***power supply limits*** and the ***quench protection system***.
- ***Ramp development***
- Ramp development follows with 6-12 bunches/ ring. Care is taken to avoid transverse emittance growth to avoid losses in the aperture limiting triplets. The ramps are done with **tune & coupling feedback**. Orbits are corrected to to 0.1-0.2 mm rms
- ***Store set-up***
- We tune for **lifetime** at store (orbit, tunes, coupling, and chromaticity), then steer for **collisions**, compare rates and test **collimation**. **Optics** measurements with the AC dipole follow. Measured β^* are typically in within 10-15% from nominal, and β^* is also verified with **Vernier scans** in operation.
- ***Test of physics ramp and store***
- We test the new configuration with a **physics store** (56-109 bunches/ring for ramp transmission, collimation, experimental backgrounds. If successful we can use the lower β^* in operations. We then readjust **non-linear corrections** for the new configuration, namely local IR triplet correction and possibly non-linear chromaticity corrections.

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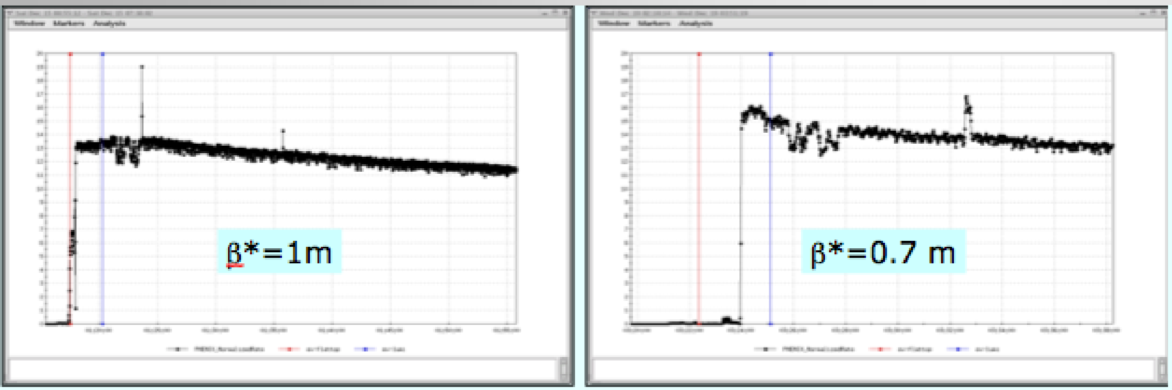
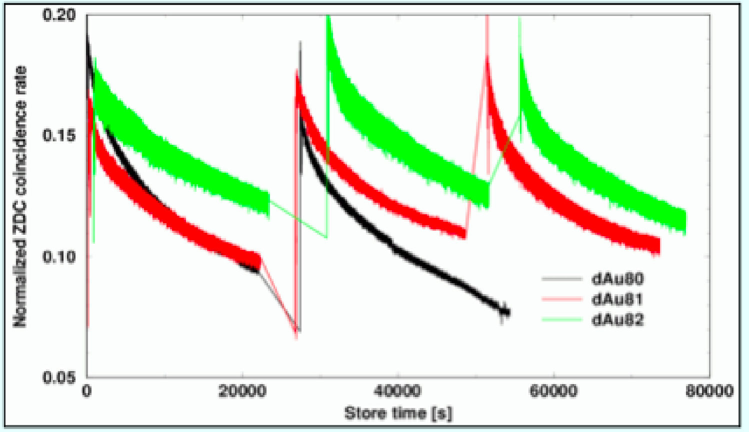
Example results: d-Au Run-8

- We first reduced β* in the **yellow ring** (gold), where we ran a lattice with higher phase advance per arc cell to minimize intra beam scattering effects. After 2 attempts, the 3rd ramp with tune & coupling feedback brought the beam to store with good transmission
- A 56x56 physics ramp allowed us to establish that the normalized collision rates ratios between the baseline (yellow at 1m) and the one with squeezed optics (yellow at 0.70m) yielded the expected **15% luminosity increase**.



Comparison of collision rates normalized for total store intensity in the expected 15% ratio



- Once we established the feasibility of operations with yellow at β*=0.7m, we repeated the development for the **blue ring**, running deuterons. The entire development took an integrated **beam time of ~24h**, over a few days. We ran the reminder of the d-Au run with β*=0.7m in both rings, gaining **~30% in integrated luminosity increase** for the run.

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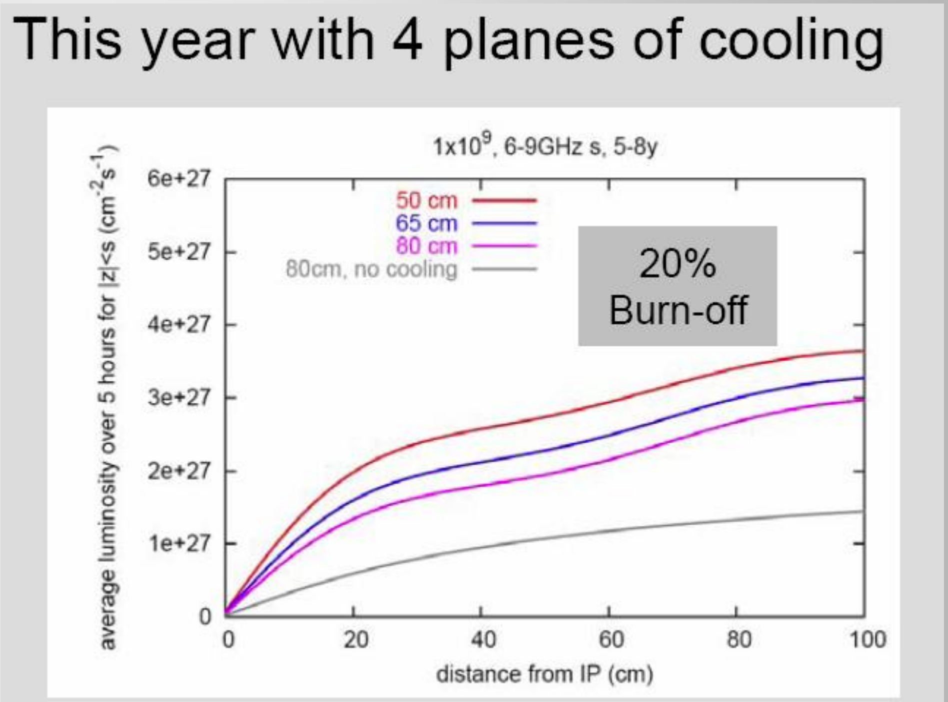
Dynamic beta* squeeze– Motivation

- Run10: longitudinal and vertical **Stochastic Cooling** (SC) should be operational => potential for luminosity increase improve luminosity by a ~factor 2



- **To help reaching higher peak luminosity, an application is being developed using the RHIC online model to further push the squeeze of β* in the experimental insertions IR6 and IR8.**

M. Brennan & M. Blaskiewicz, RHIC S&T Review 2009

- The goal is to have an application similar to the one used for orbit correction at store: β* as a function of time should follow the change in emittance as achieved by SC.

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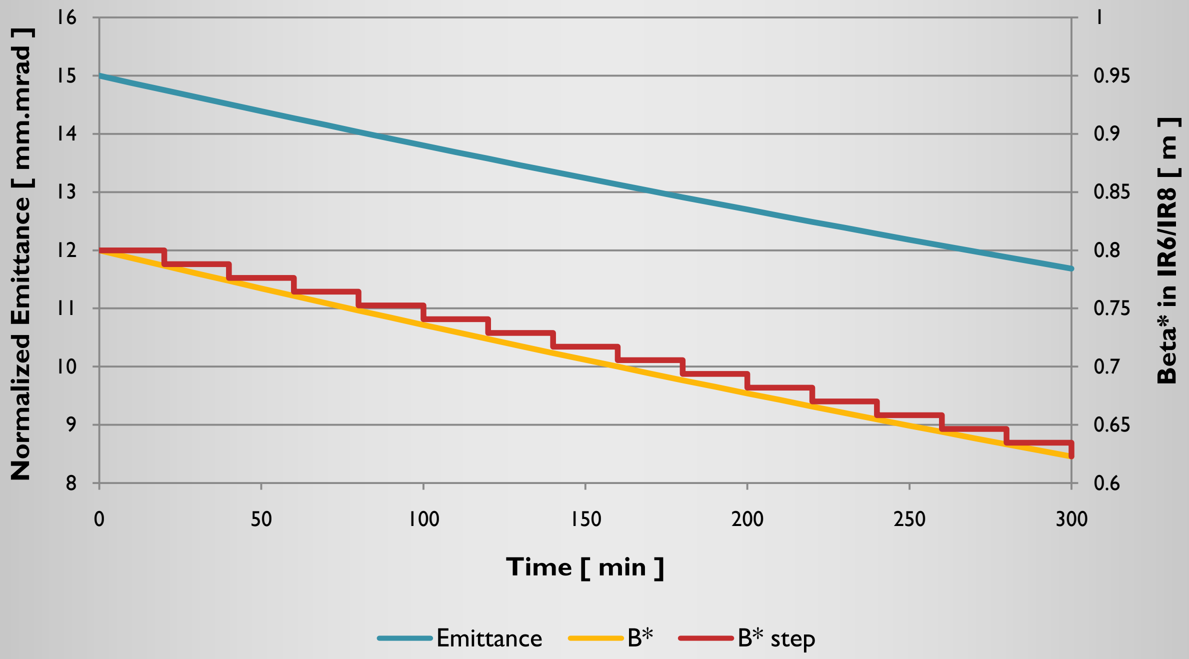
Dynamic beta* squeeze: Plans for Run10

- Test the online model for limitations on squeeze steps.
- Main goal: use the effect of SC on emittance changes along a store to increase luminosity by dynamically reducing β* (i.e. keep the ratio ε/β* constant).



- This can be done in stages: first a **step function**, then a **fitted polynomial** (matching SC effect on beam emittance once the system is fully commissioned).

Tevatron beam studies

- Beta squeeze with protons ?
- Local triplet corrections ?
- Working point next to the integer?
- Dynamic Aperture ? (see Mei Bai presentation)

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