Transition energy jump at RHIC

Quadratic and linear jump

RHIC implementation

Fast transverse instability

Operating experience at RHIC

BROOKHAVEN NATIONAL LABORATORY

Thomas Roser
Project X collaboration meeting
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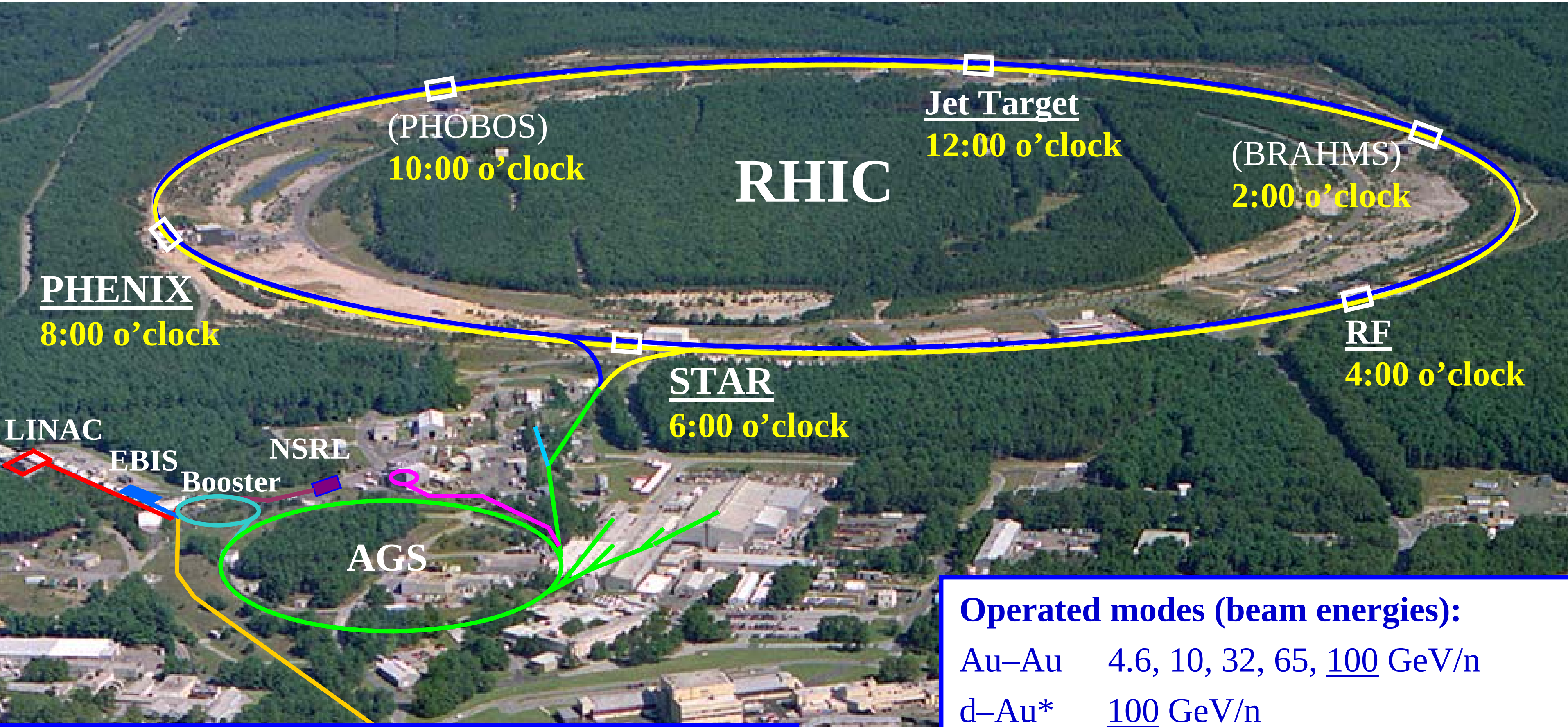
RHIC – a High Luminosity (Polarized) Hadron Collider



Achieved peak luminosities (100 GeV, nucl.-pair):

Au–Au	120×10^{30} cm^{-2} s^{-1}
p↑–p↑	35×10^{30} cm^{-2} s^{-1}

Other large hadron colliders (scaled to 100 GeV):

Tevatron (p – pbar)	32×10^{30} cm^{-2} s^{-1}
LHC (p – p, design)	140×10^{30} cm^{-2} s^{-1}

Operated modes (beam energies):

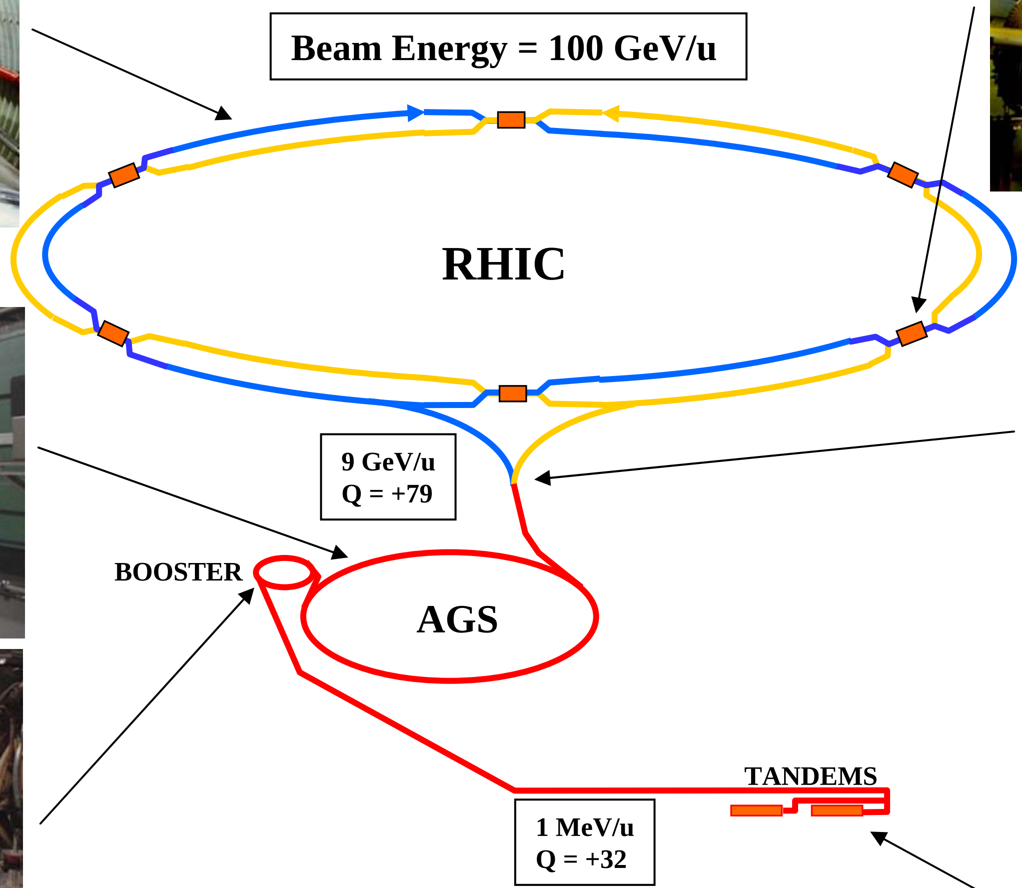
Au–Au	4.6, 10, 32, 65, 100 GeV/n
d–Au*	100 GeV/n
Cu–Cu	11, 31, 100 GeV/n
p↑–p↑	11, 31, 100 GeV

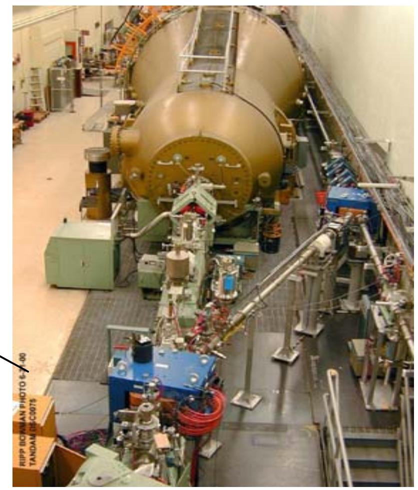
Planned or possible future modes:

p↑–p↑	250 GeV
Au – Au	2.5 GeV/n (~ SPS cm energy)
p↑ – Au*	100 GeV/n

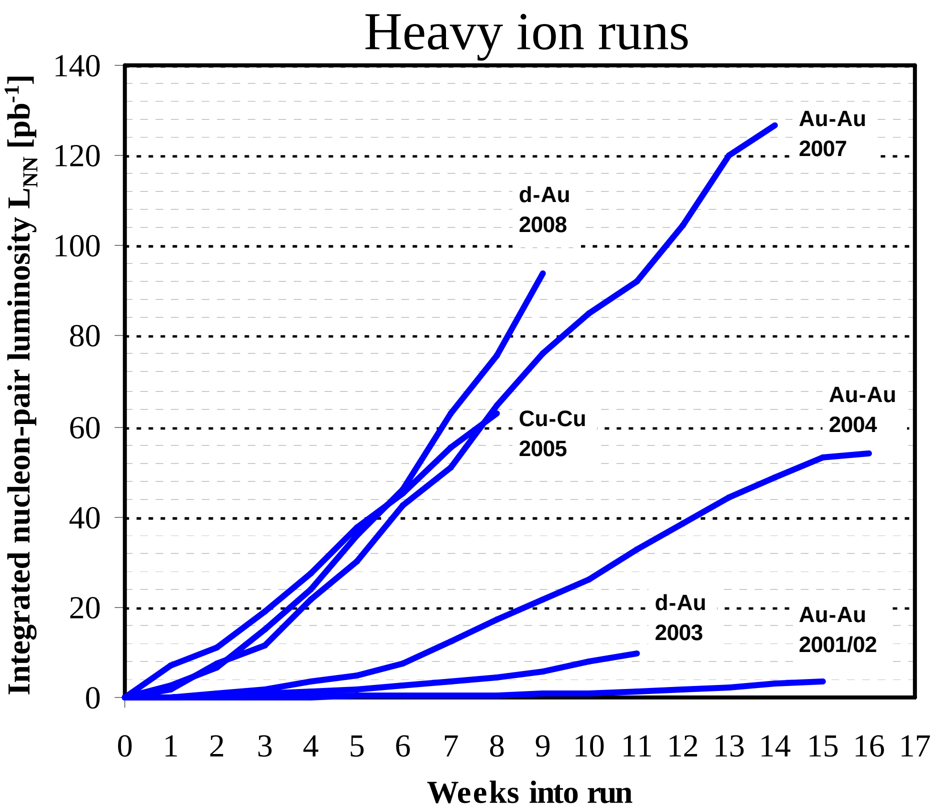
(*asymmetric rigidity)

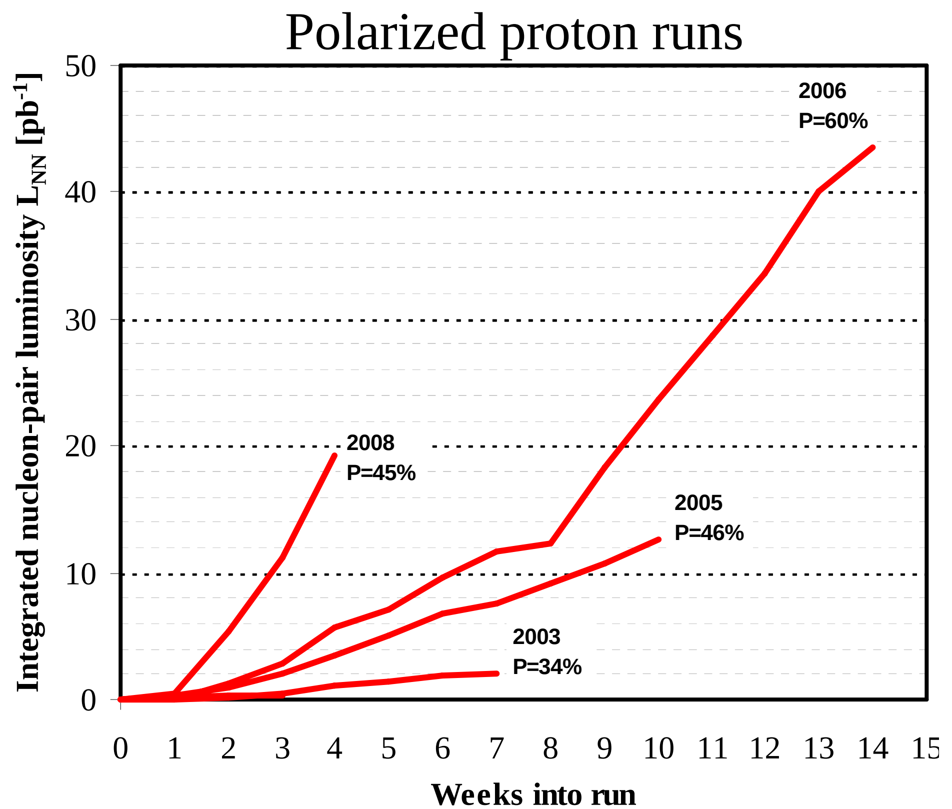
Gold Ion Collisions at RHIC





Delivered Integrated Luminosity and Polarization





<u>Nucleon-pair luminosity</u>: luminosity calculated with nucleons of nuclei treated independently; allows comparison of luminosities of different species; appropriate quantity for comparison runs.

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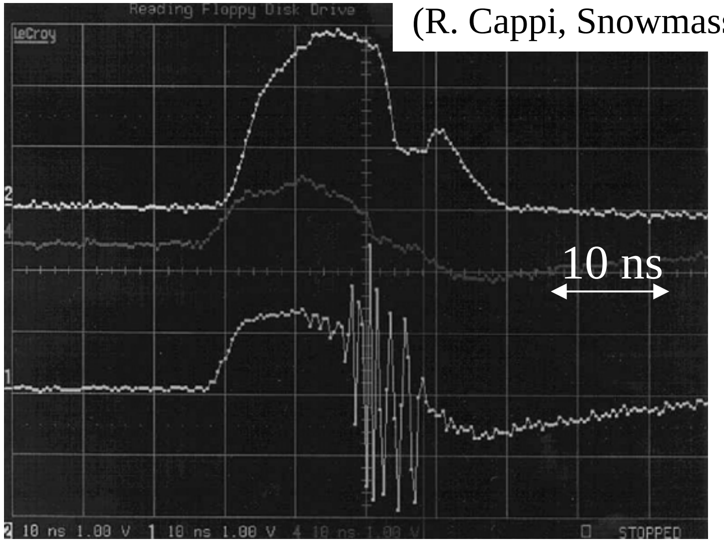
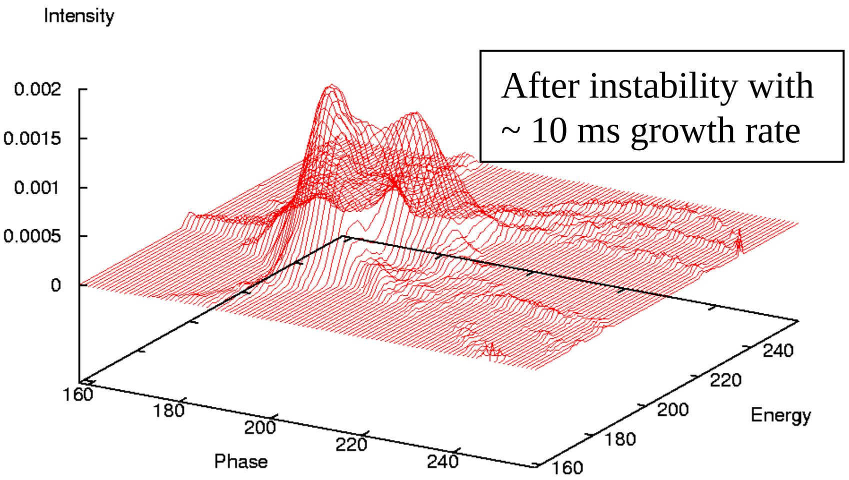
Single bunch transverse instabilities

- CERN PS transition (~ 7 GeV)
- 7×10^{12} ppb, > 2.2 eVs
- Occurs close to transition
- Cured with long. blow-up and non-zero chromaticity



(R. Cappi, Snowmass 2001)

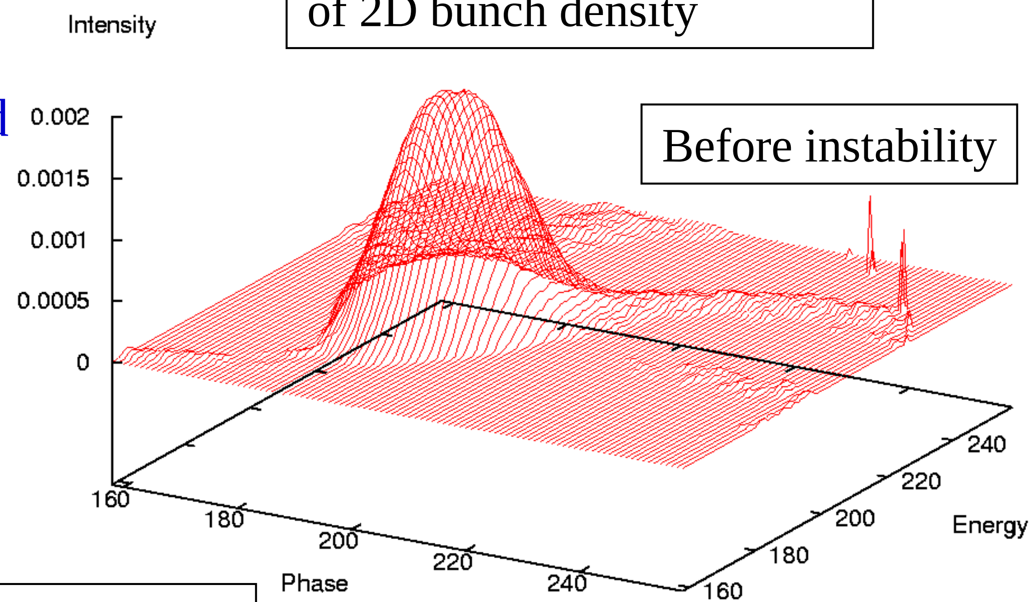
- RHIC transition (~ 20 GeV/n)
- 1.5×10^{11} cpb, ~ 0.3 eVs/n
- Occurs close to transition
- Cured with octupoles and non-zero chromaticity



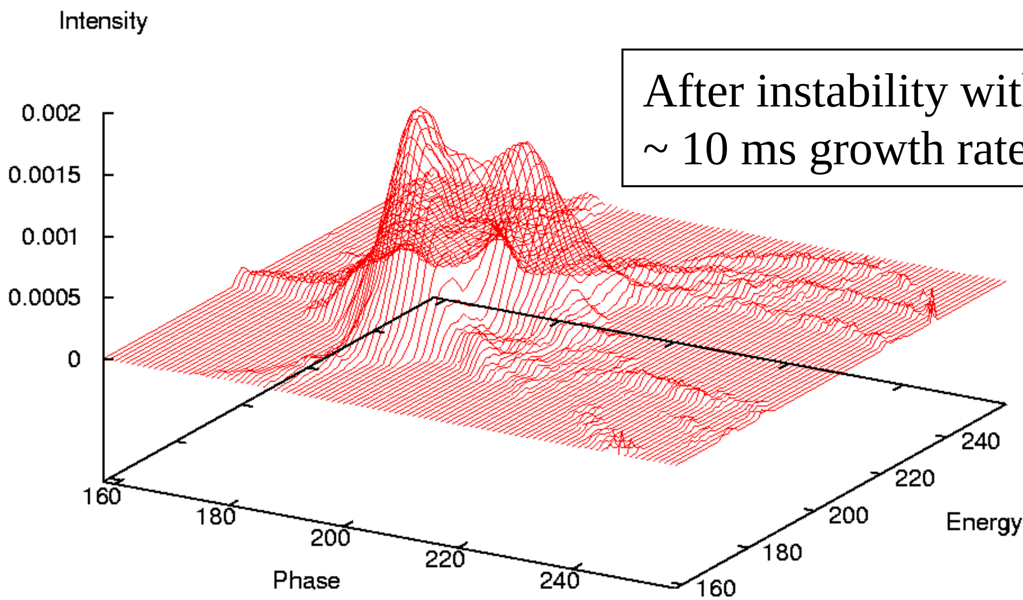
Luminosity Limit – Fast Instability Near Transition

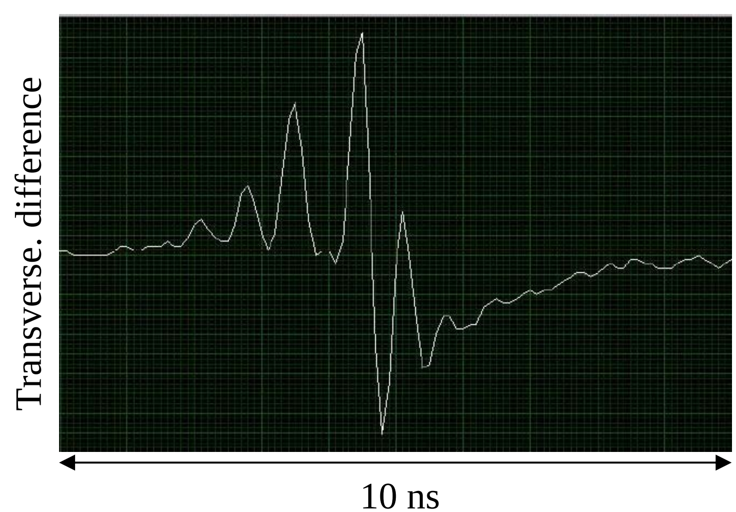
- Fast transverse instability (~ GHz)
- High sensitivity around transition
  (high peak current, zero chromaticity)
- Effect of broadband impedance and electron clouds
- Cures: octupoles, suppress electron clouds, chromaticity jump, active damper (?)

Tomographic reconstruction of 2D bunch density



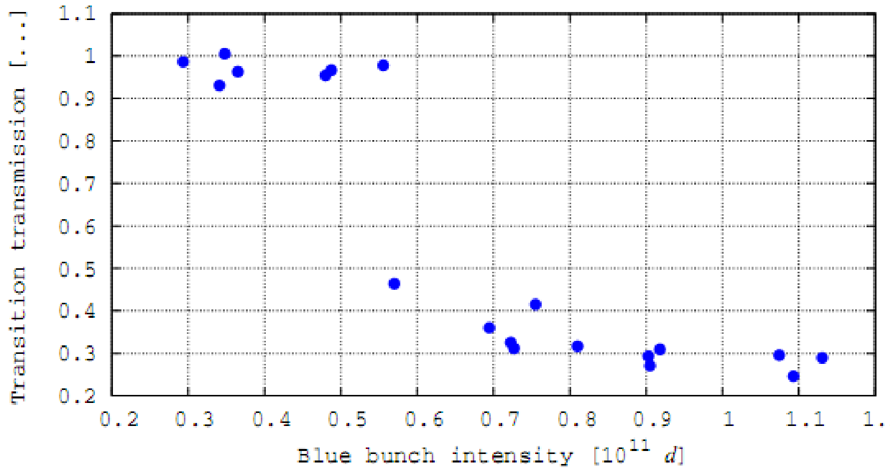
After instability with ~ 10 ms growth rate



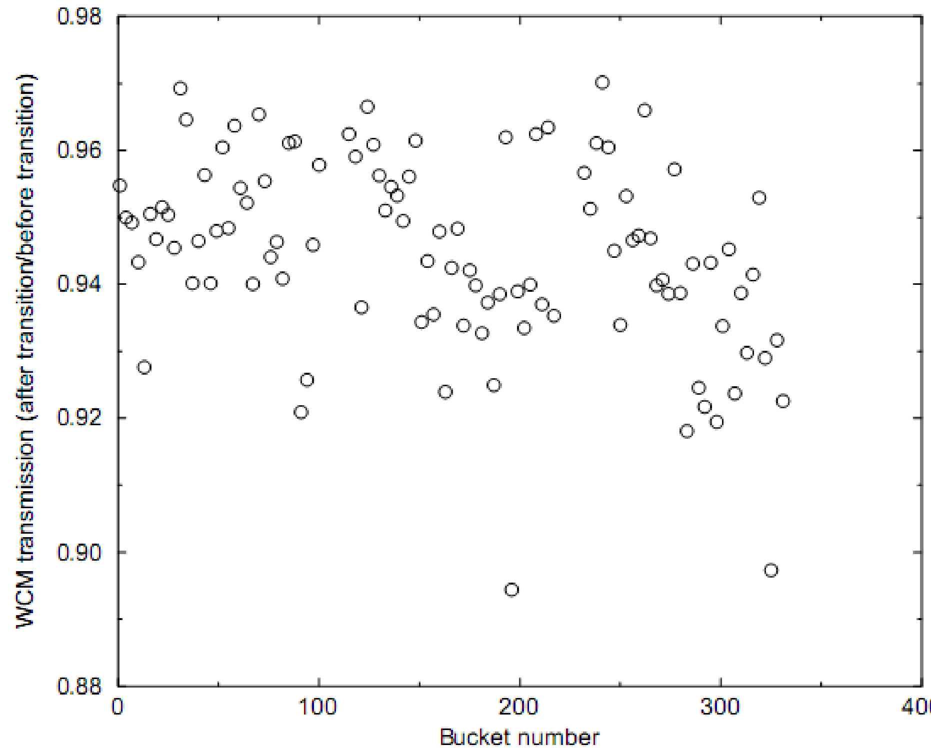


Evidence for electron cloud

- Intensity threshold without octupoles



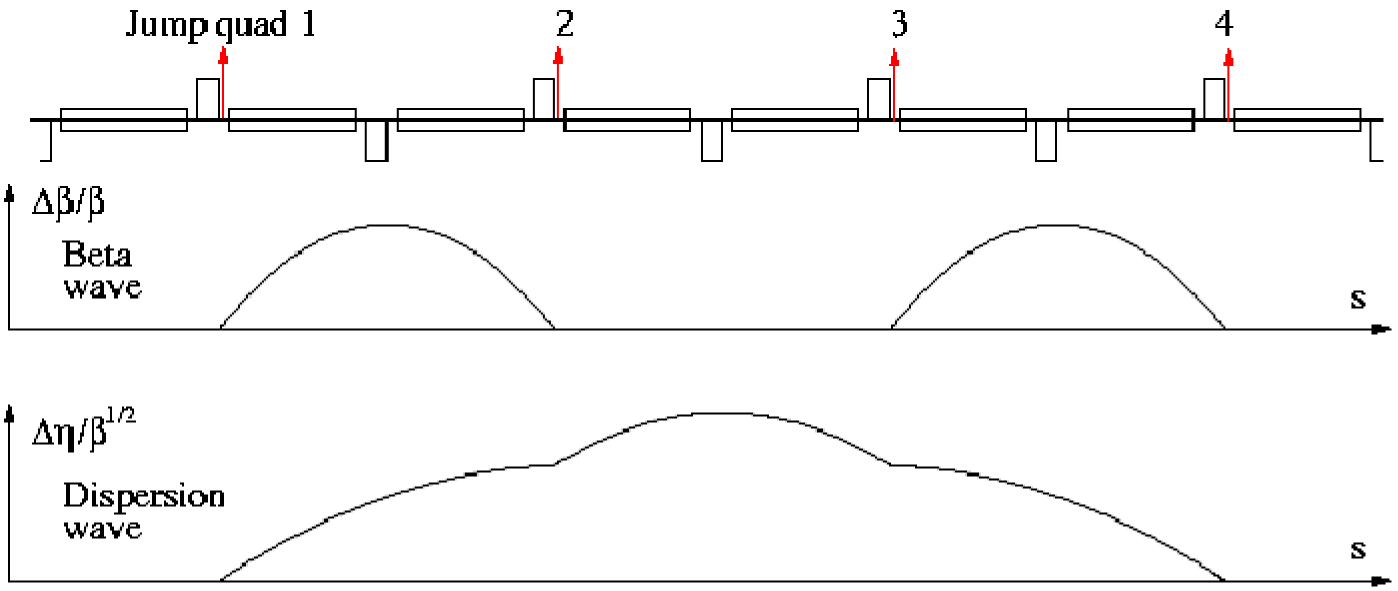
- Intensity loss at end of bunch trains



γ_T jumps in AGS and RHIC

- γ_T jump in AGS is quadratic: γ_T changes with the square of the jump quadrupole current or only in one direction
  - Equal number of positive and negative distributed jump quadrupoles generate a large dispersion wave and no tune shift and no first order γ_T shift, only a second order shift.
- γ_T jump in RHIC is linear: γ_T changes linearly with the jump quadrupole current. The jump is bi-polar.
  - One set jump quadrupoles generate a local dispersion bump, which linearly changes γ_T. They also generate local beta waves that shift the betatron tune.
  - A second set is located in a dispersion-free region and generates a local λ beta wave to correct tune shift.
- There are six sets of dispersion and beta wave jump systems at RHIC to give a total γ_T jump of -2 units.
- Dispersion bump should also generate a + 3 unit H + V chromaticity jump due to chromaticity sextupoles

RHIC linear γ_T jump scheme



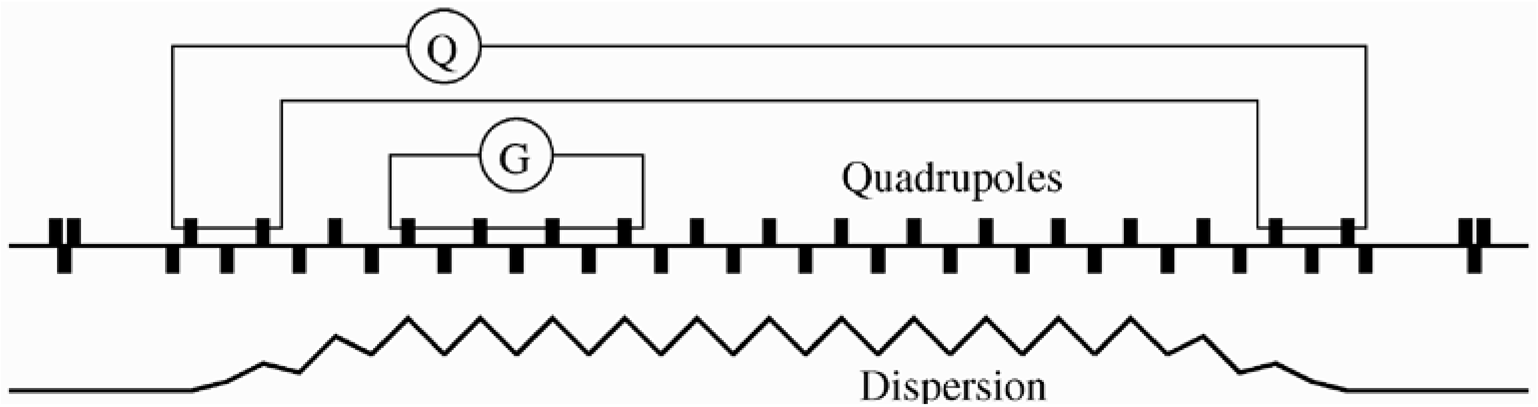
Beta waves advance twice as fast as dispersion waves

Pairs of jump quad doublets confine dispersion

Real phase advances are never exactly 90 degrees

D. Trbojevic, S. Peggs

RHIC implementation

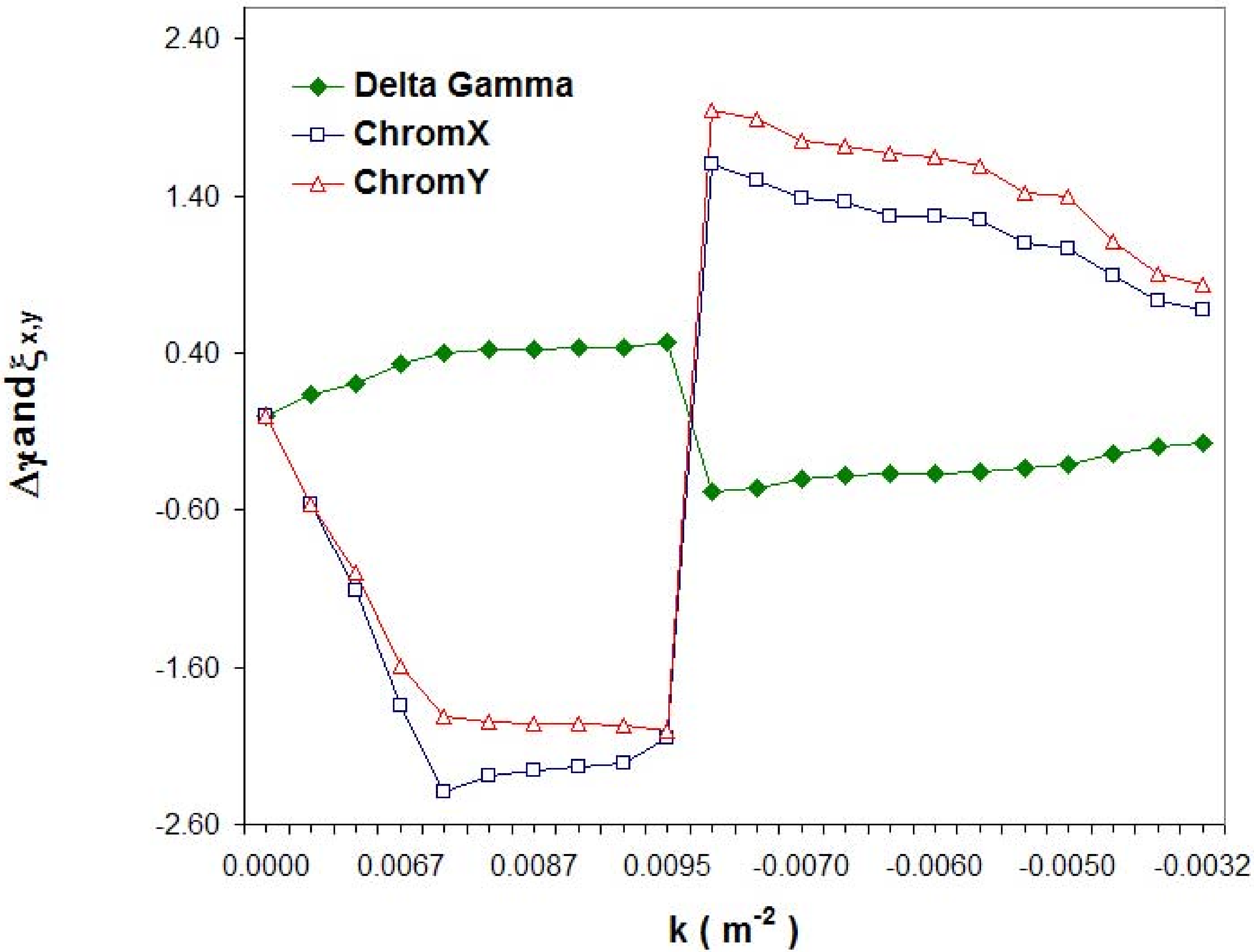


G families change γ_T, Q families compensate tunes

Unoptimized optics:

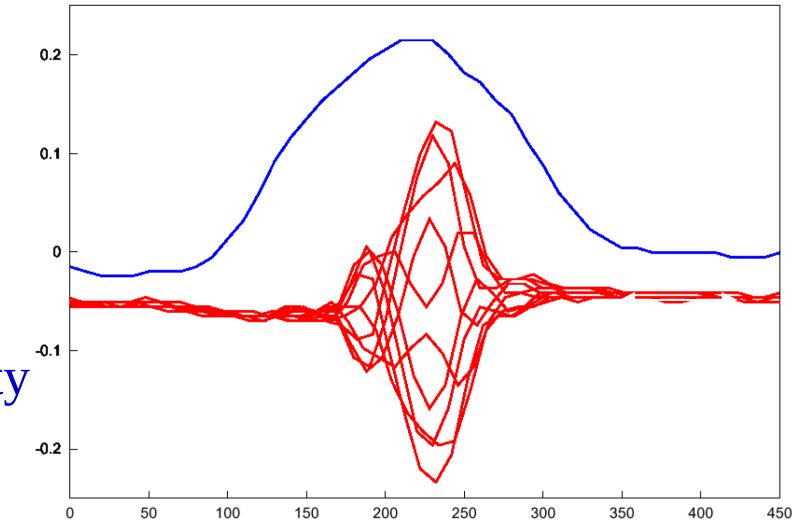
1) some dispersion leaks into the Q family
2) phase advances are not constant, or near 90 degrees

$\Delta\gamma_T$ and chromaticity jump from RHIC model

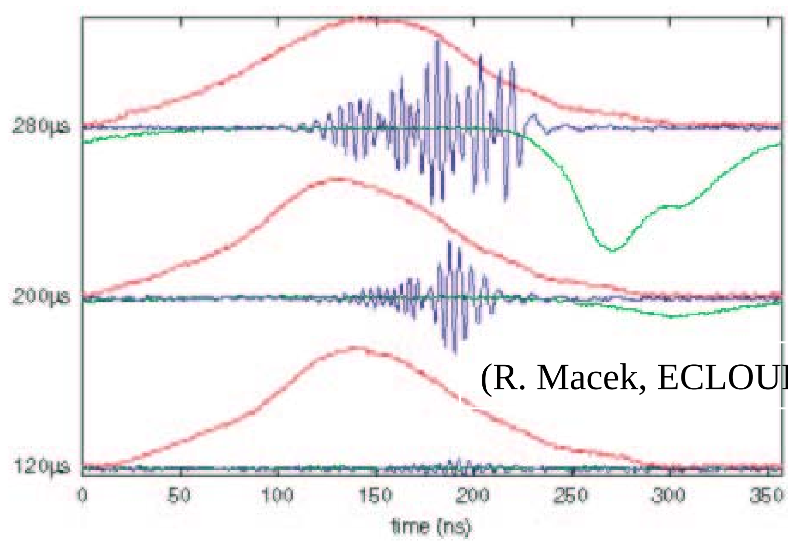


Single bunch transverse instabilities – I_{peak} limitation

- AGS Injection (1.9 GeV)
- 12×10^{12} ppb, ~ 3 eVs
- Single bunch
- Transverse pick-up bandwidth limited
- Cured with non-zero chromaticity



- LANL PSR (0.8 GeV)
- 50×10^{12} ppb
- Cured with high rf voltage



(R. Macek, ECLOUD 2004)