First Polarized Proton Collision at RHIC

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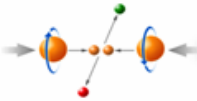
Outline



- Introduction
  - Spin dynamics in RHIC
  - RHIC polarized proton setup
- RHIC 250 GeV polarized proton run
  - Luminosity performance
  - Polarization performance
- Summary & Future Plan

Spin Dynamics: Thomas-BMT Equation

$$\frac{d\vec{S}}{dt} = \vec{\Omega} \times \vec{S} = -\frac{e}{\gamma m}[G\gamma \vec{B}_{\perp} + (1+G)\vec{B}_{//}] \times \vec{S}$$

Spin vector in particle's rest frame

Magnetic field along the direction of the particle's velocity

Magnetic field perpendicular to the particle's velocity

- G is the anomoulous g- factor, for proton,
  G=1.7928474
- γ: Lorenz factor

- Spin tune Q_s: number of precessions in one orbital revolution.

$$Q_s = G\gamma$$

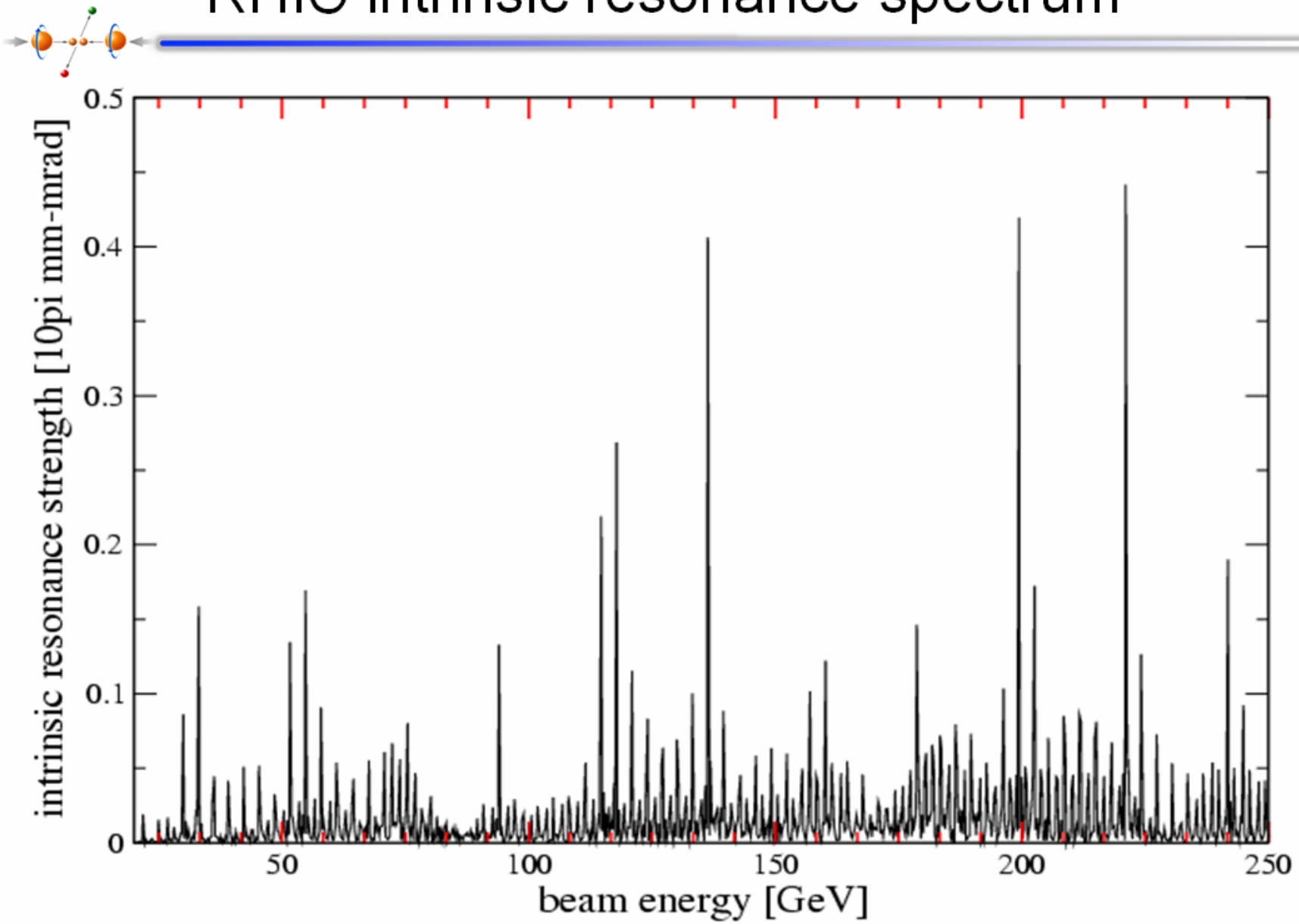
Depolarizing Mechanism

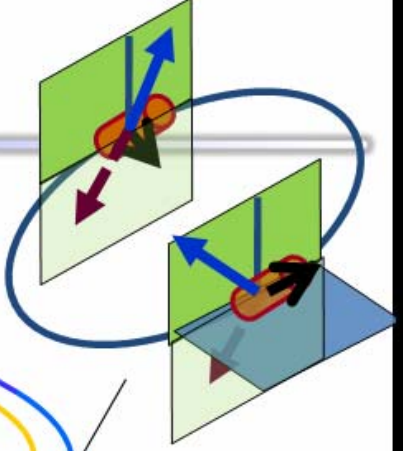
- **Spin depolarizing resonance**: when the spin vector gets kicked at a frequency close to the frequency it processes. The location of a spin depolarizing resonance is at

$$Q_s = \text{tune of the kick on the spin}$$

- **Source of depolarizing resonance**: horizontal field kicks the spin vector away from its vertical direction, and lead to polarization loss
  - Imperfection resonance: vertical closed orbit distortion
    - $G\gamma=k$
      - k is an integer
  - Intrinsic resonance: vertical betatron oscillation
    - $G\gamma=kP \pm Qy$
      - Qy is the vertical betatron tune, P is the periodicity of the lattice

RHIC intrinsic resonance spectrum





Absolute Polarimeter (H jet)

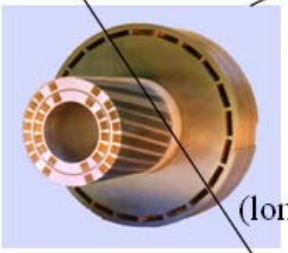
RHIC pC Polarimeters

BRAHMS(p)

PHENIX (p)

STAR (p)

RF cavities



Spin Rotators
(longitudinal polarization)

Spin Rotators
(longitudinal polarization)

Solenoid Partial Siberian Snake

LINAC

BOOSTER

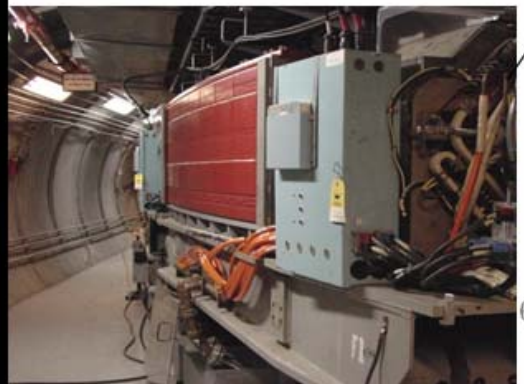
Pol. H^- Source

200 MeV Polarimeter

AGS

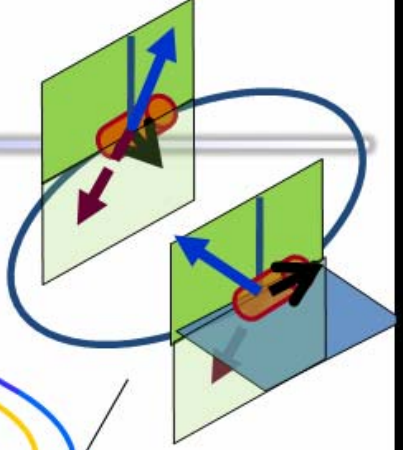
Helical Partial
Siberian Snake

AGS Polarimeters



Siberian Snakes:

- two Siberian snakes located on the opposite sides of ring
- their axes perpendicular
  - ➢ Spin tune =1/2



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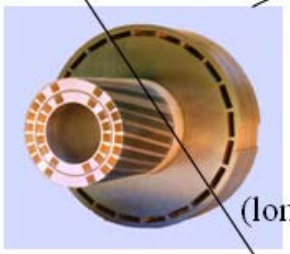

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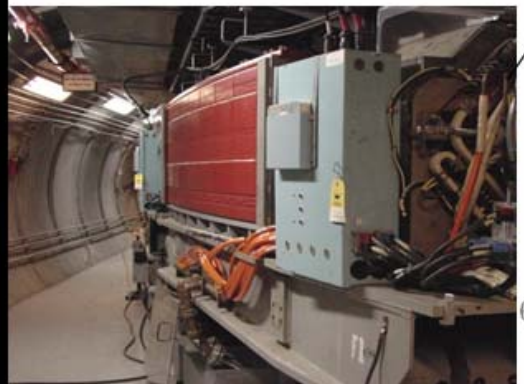
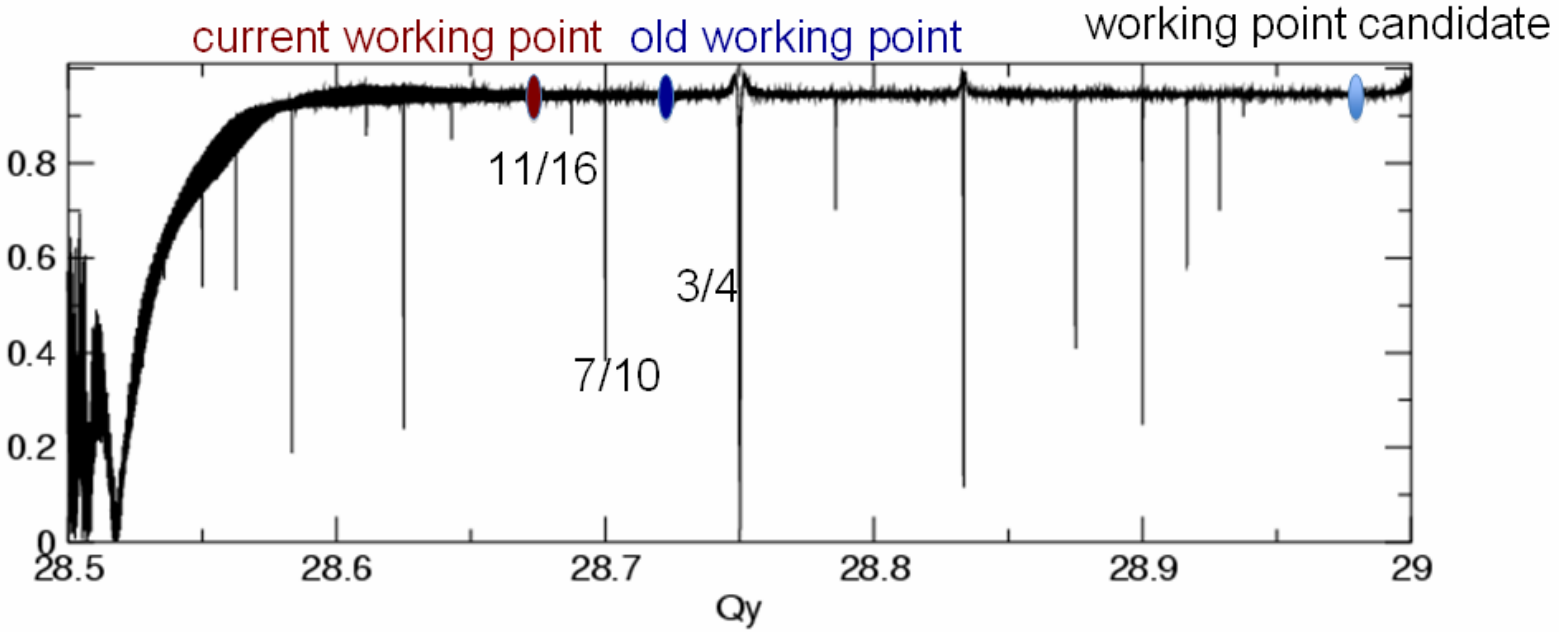


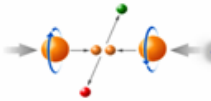
RHIC polarized proton setup

- Precise control of work point and closed orbit distortion to avoid snake resonances at

$$mQ_y = Q_s + k$$

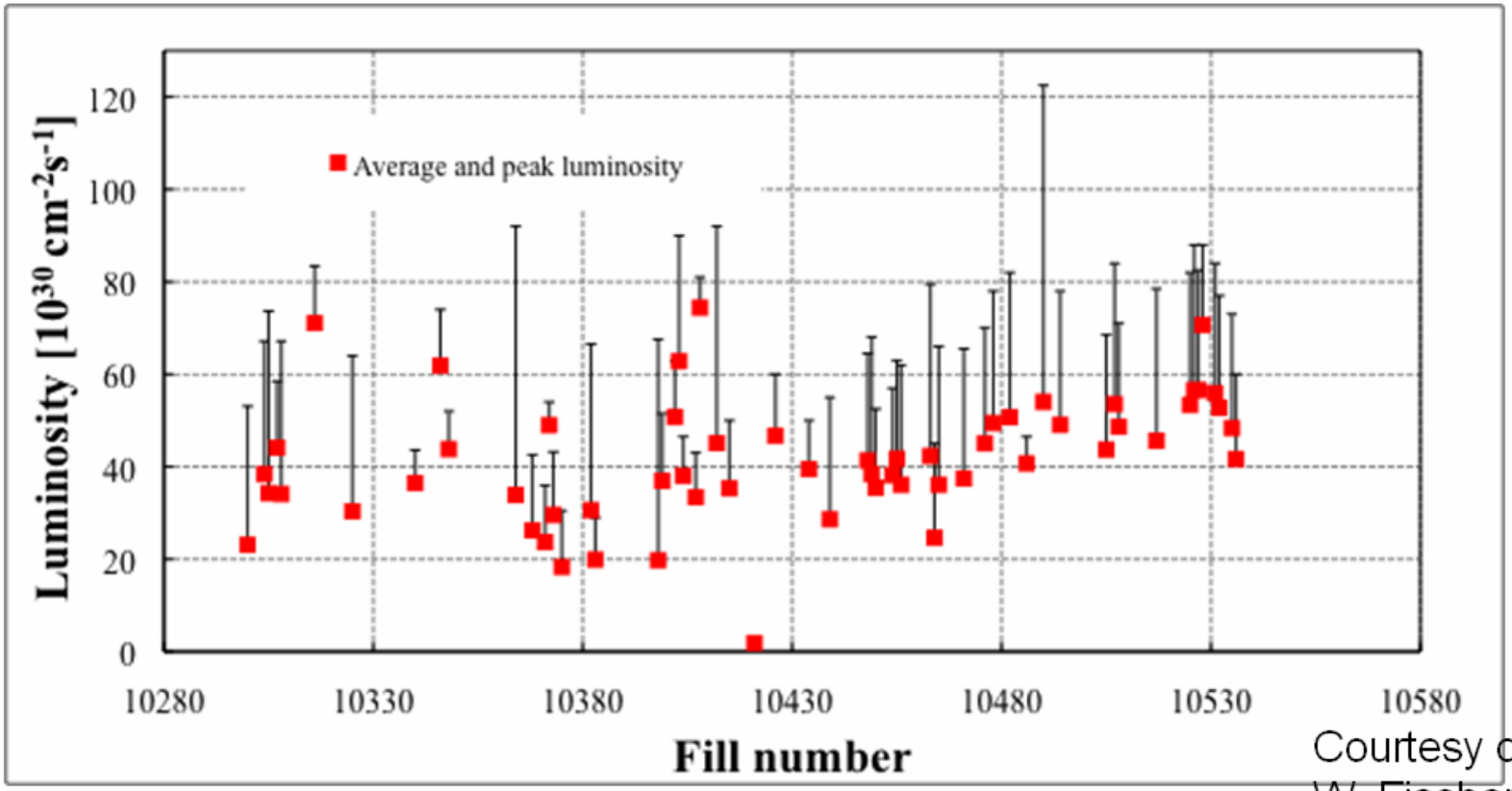
  - odd m: odd order resonance: driven by the intrinsic resonance
  - even m: even order resonance





RHIC 250 GeV polarrized proton run performance

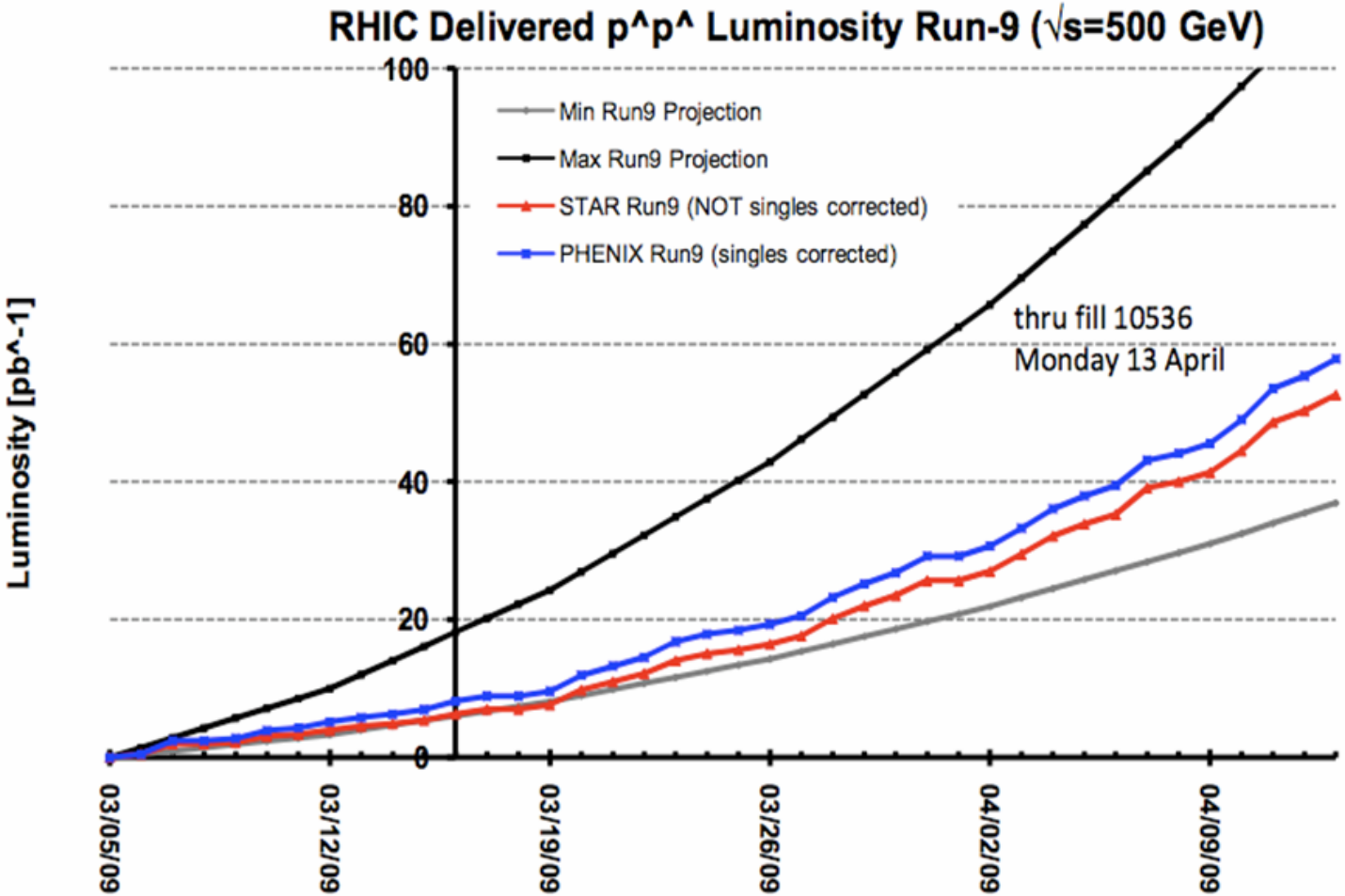
Luminosity performance



Courtesy of W. Fischer

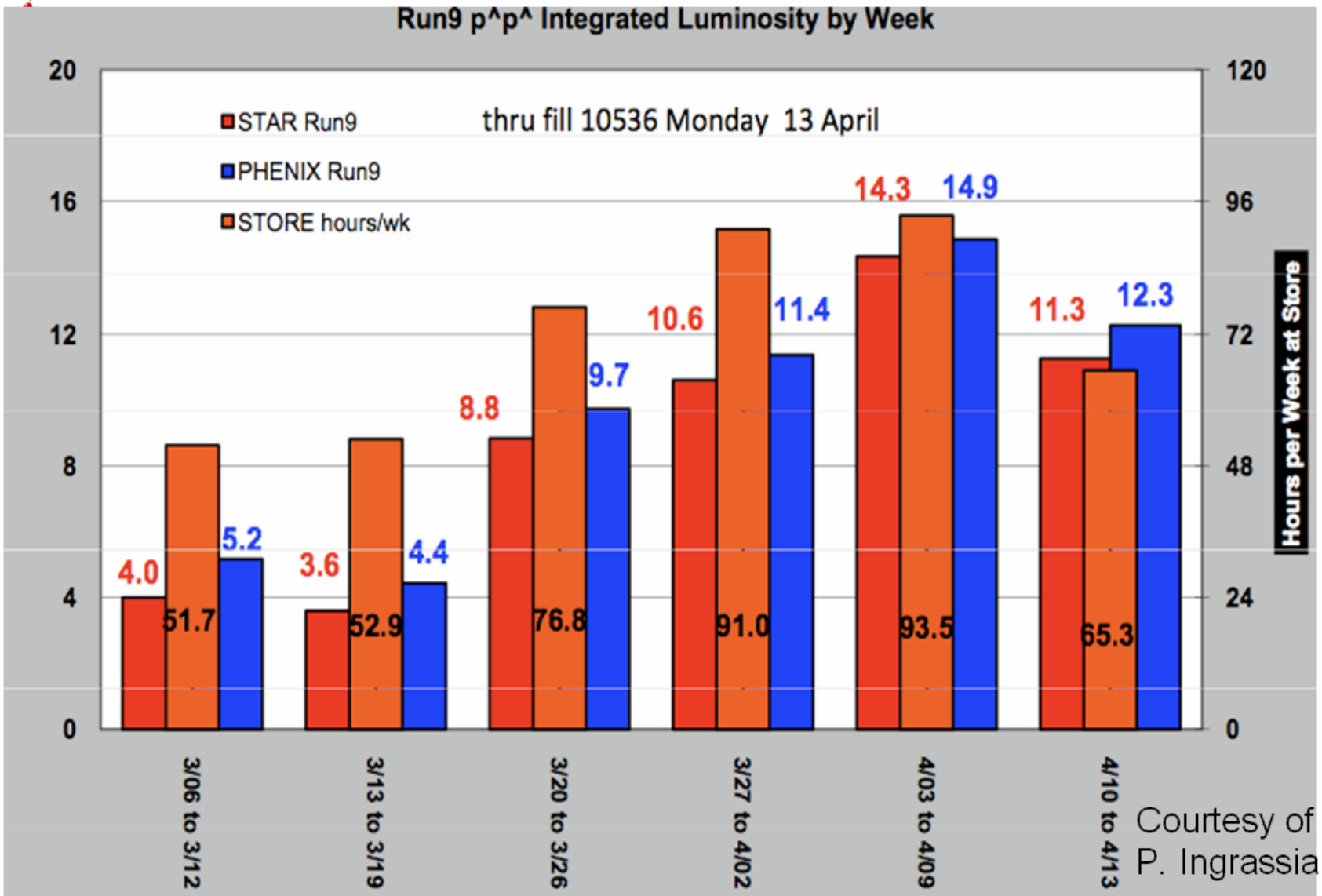
- beta*: 0.7m
- # of bunches: 109
- Bunch intensity: 1.2x10^11 protons

Integrated Luminosity



Courtesy of
P. Ingrassia

Weekly Luminosity



Courtesy of
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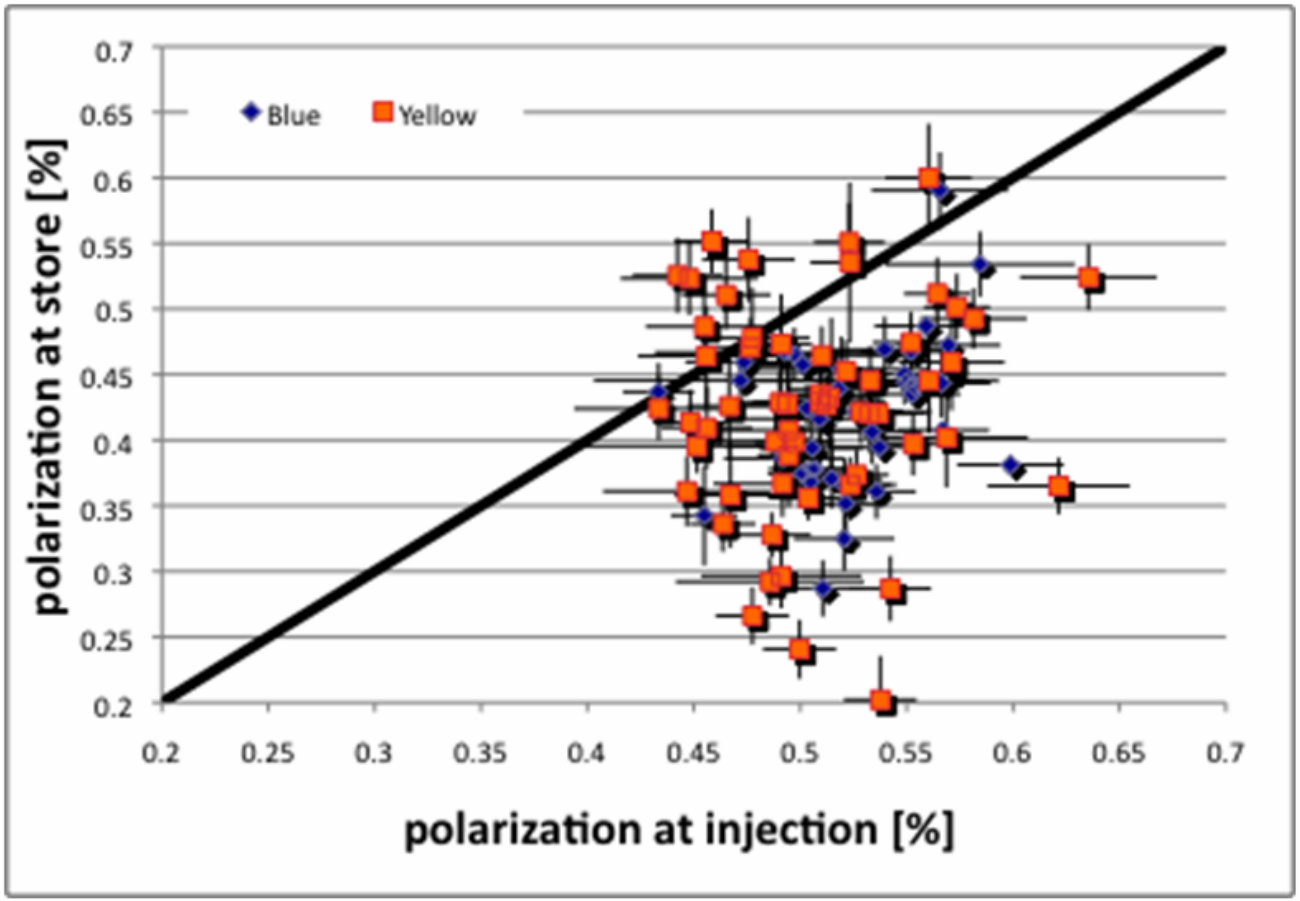
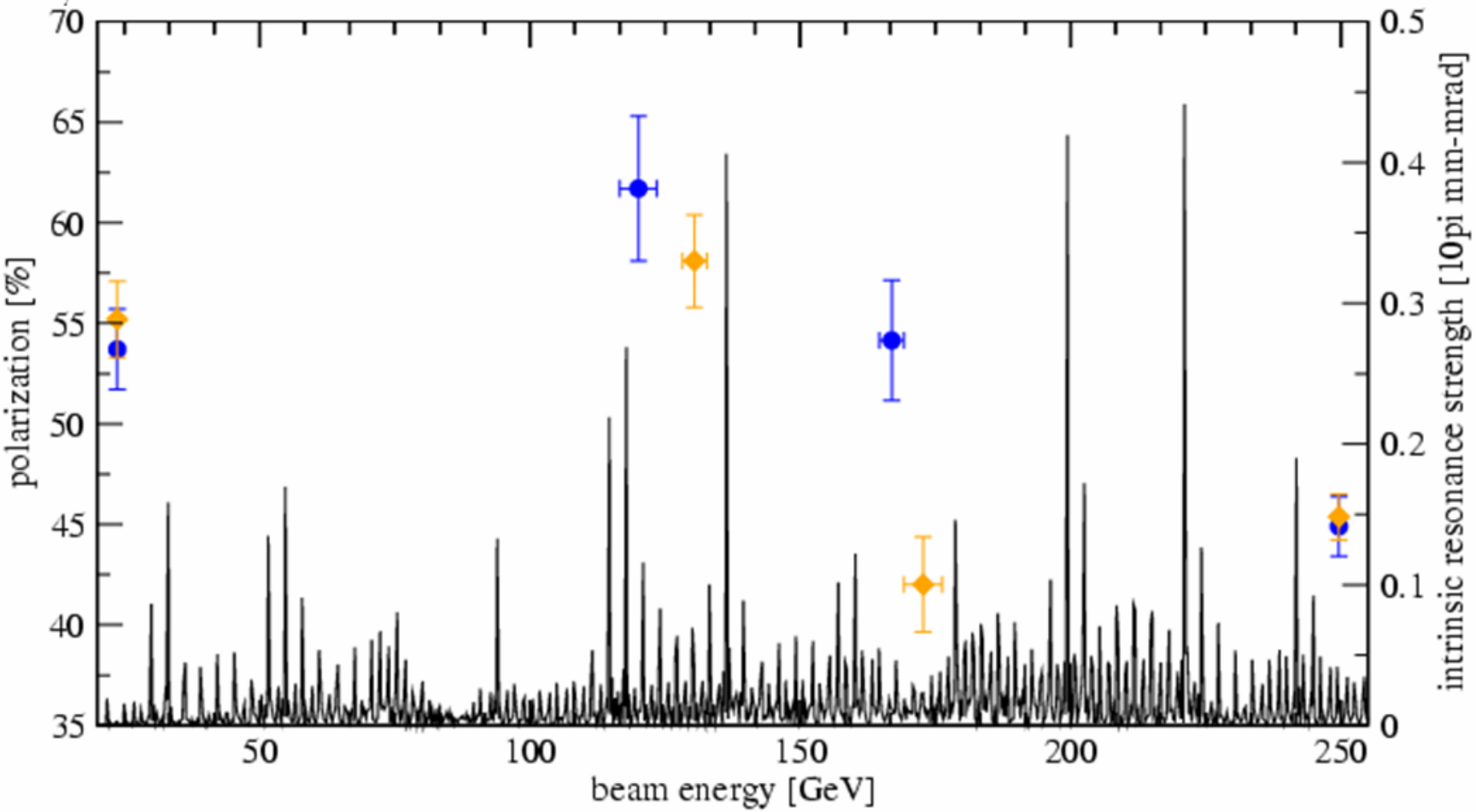
Polarization performance



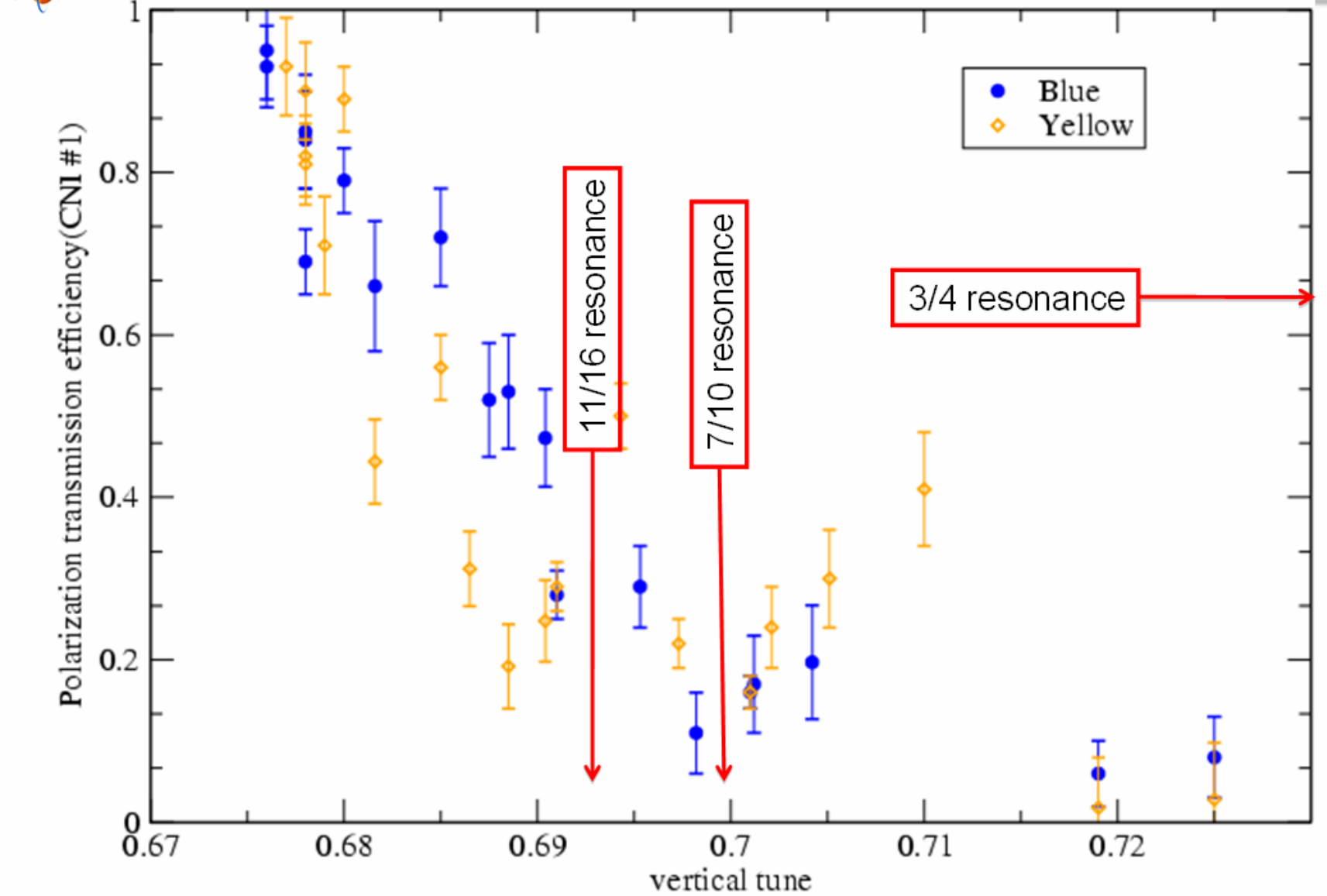
- Average beam polarization: ~42%
- Best polarization achieved: ~54%

Polarization Ramp Measurement

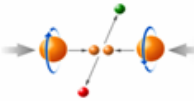


- No polarization loss up to 136 GeV
- candidate of depolarization location: the three strong intrinsic resonances after 100 GeV, around 136GeV, 199 GeV and 221 GeV

Polarization tune scan above 100GeV



Summary & Plan



- Achieved operational 109x109 with 1.2×10^{11} protons per bunch
- An average of ~42% polarization was achieved at 250~GeV
- Demonstrated that the current 250 GeV machine setup was able to accelerate/collide 56x56 with 1.8×10^{11} bunch. Polarization was ~30% in both rings
- To preserve 100% polarization to 250GeV, following options are under investigation
  - Minimize the width of 3Qy=2 resonance to accommodate Qy<=0.675
  - Accelerate with near integer work point ~(0.96, 0.97)