Analysis of Polarization Decay at RHIC Stores

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U.S. DEPARTMENT OF ENERGY

BROOKHAVEN NATIONAL LABORATORY

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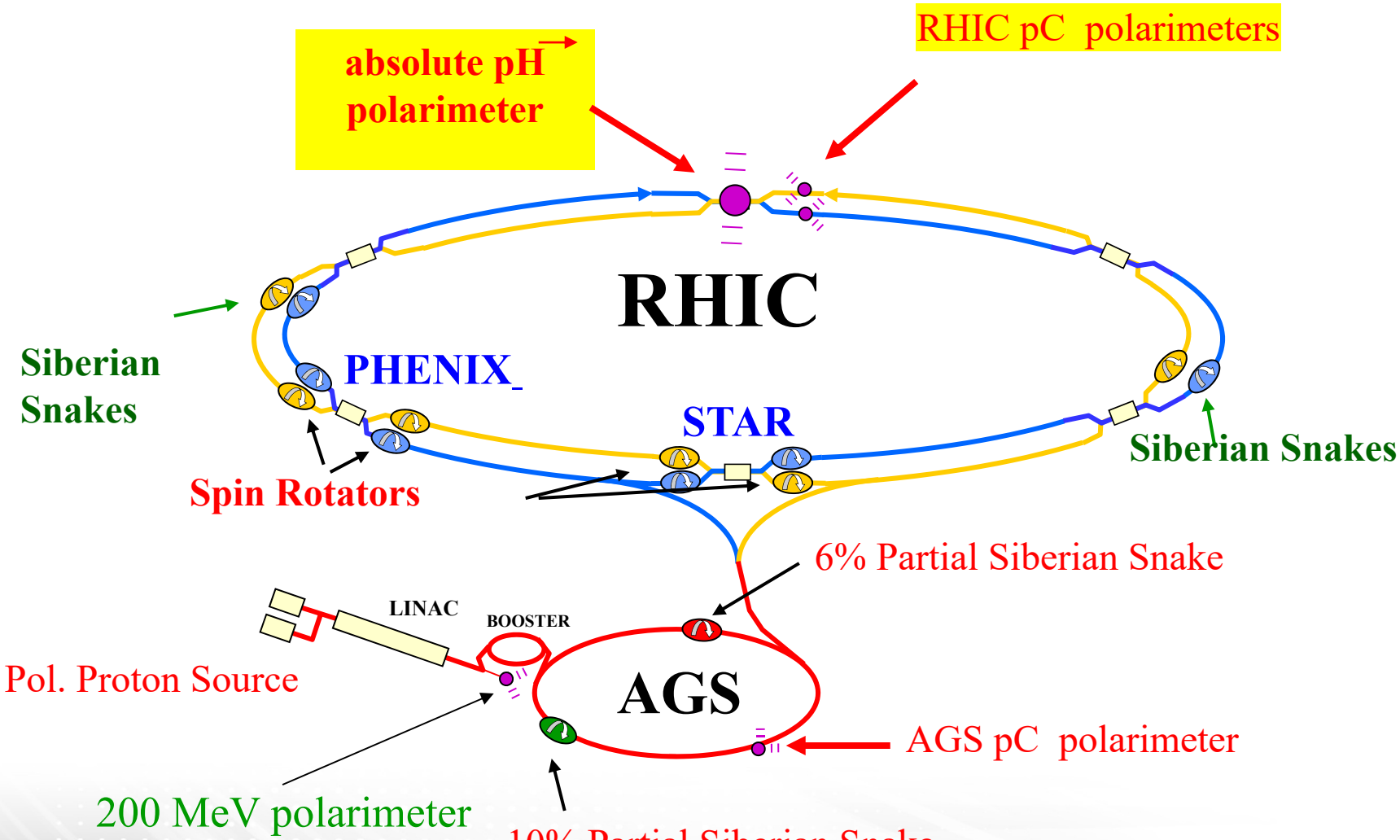
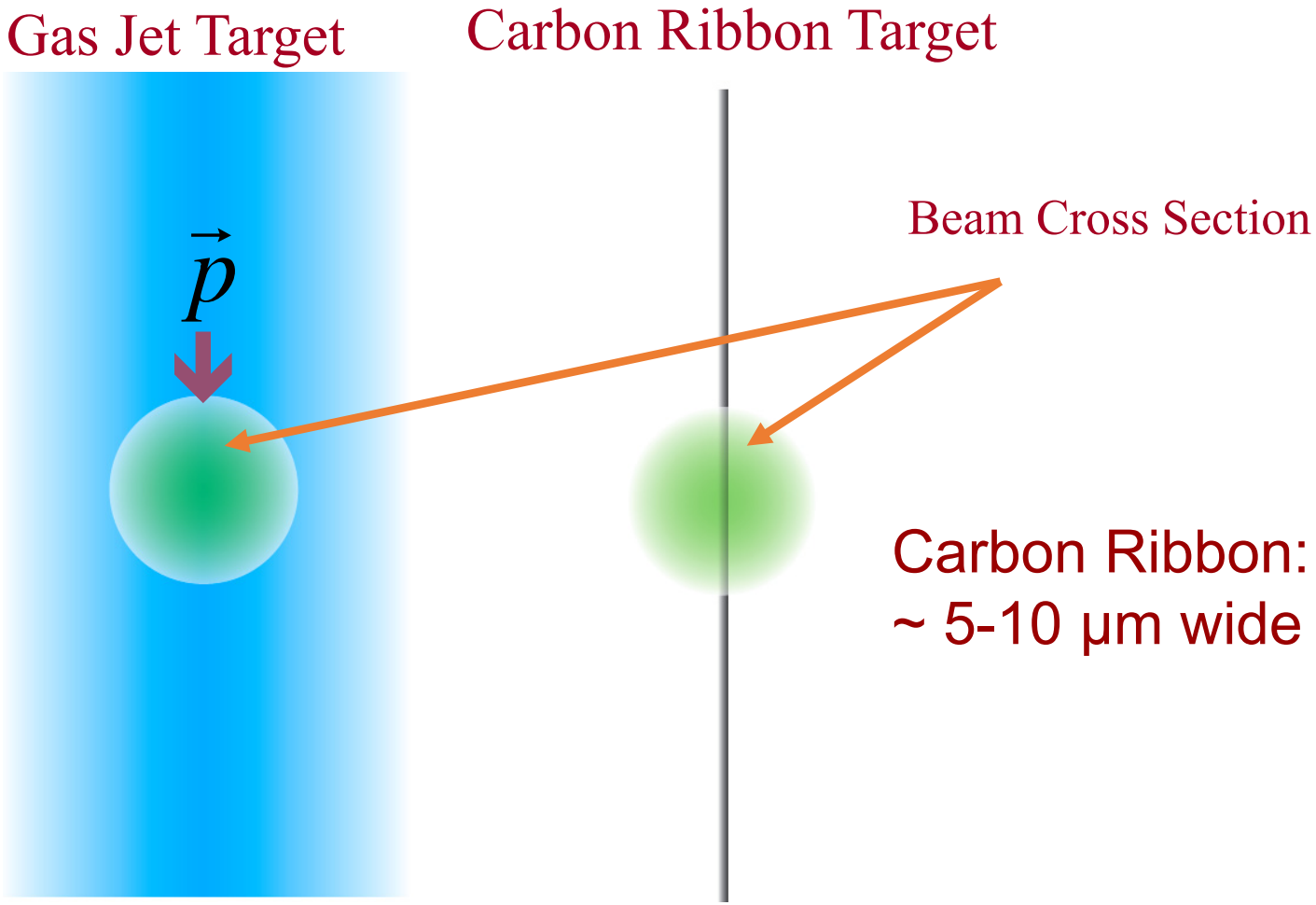
RHIC *pp* Accelerator Complex



Hydrogen Gas Jet and Carbon Ribbon Targets

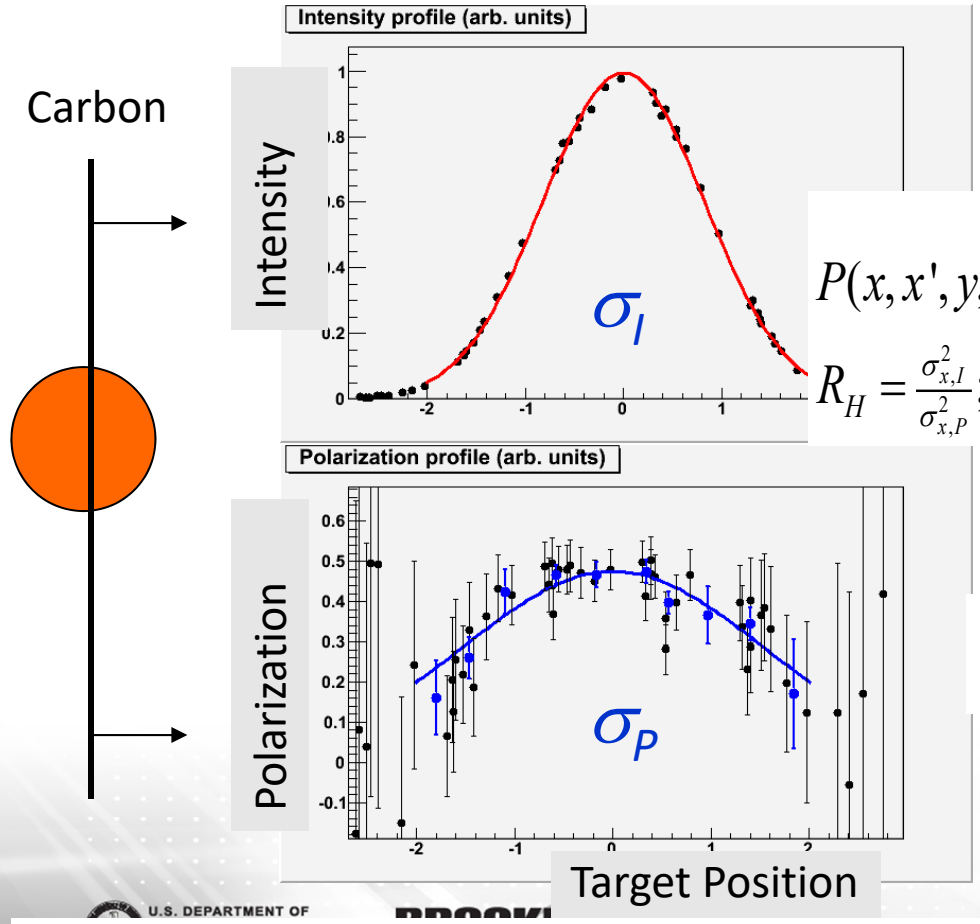


Average Polarization P_{ave}

Peak(P_{peak}) and average Polarization P_{ave}

Polarization Profile and Average Polarization

- Polarization loss from intrinsic and snake resonances: more polarization lost at edge of beam → polarization profile.
- Impact of polarization profile on average beam polarization:



$$R = \frac{\sigma_I^2}{\sigma_P^2}$$

$$P(x,x',y,y') = P_0 e^{-\frac{x^2+x'^2}{2\sigma_{x,P}^2}} e^{-\frac{y^2+y'^2}{2\sigma_{y,P}^2}}; \quad I(x,x',y,y') = I_0 e^{-\frac{x^2+x'^2}{2\sigma_{x,I}^2}} e^{-\frac{y^2+y'^2}{2\sigma_{y,I}^2}};$$

$$R_H = \frac{\sigma_{x,I}^2}{\sigma_{x,P}^2}; \quad R_V = \frac{\sigma_{y,I}^2}{\sigma_{y,P}^2}; \langle P \rangle = P_0 \frac{1}{(1+R_H)(1+R_V)}$$

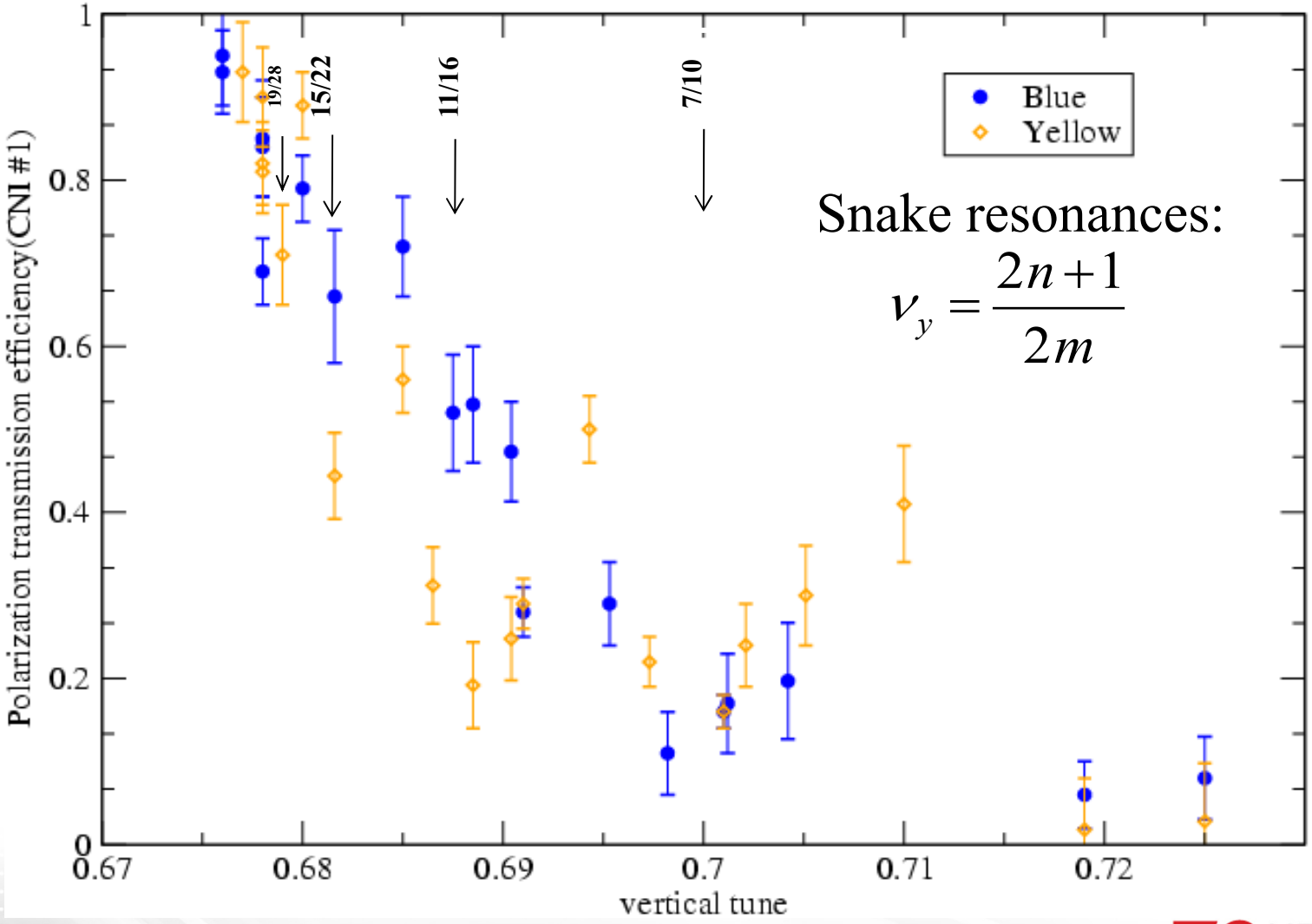
Ideal case: flat pol. profile ($\sigma_P = \infty \Rightarrow R = 0$)

For $R_H \approx R_V = R$ and small:

$$P_{ave} = \frac{P_0}{(1+R)^2}$$

W. Fischer and A. Bazilevsky, Phys. Rev. STAB **15**, 041001(2012).

RHIC Polarization Loss due to Snake Resonances



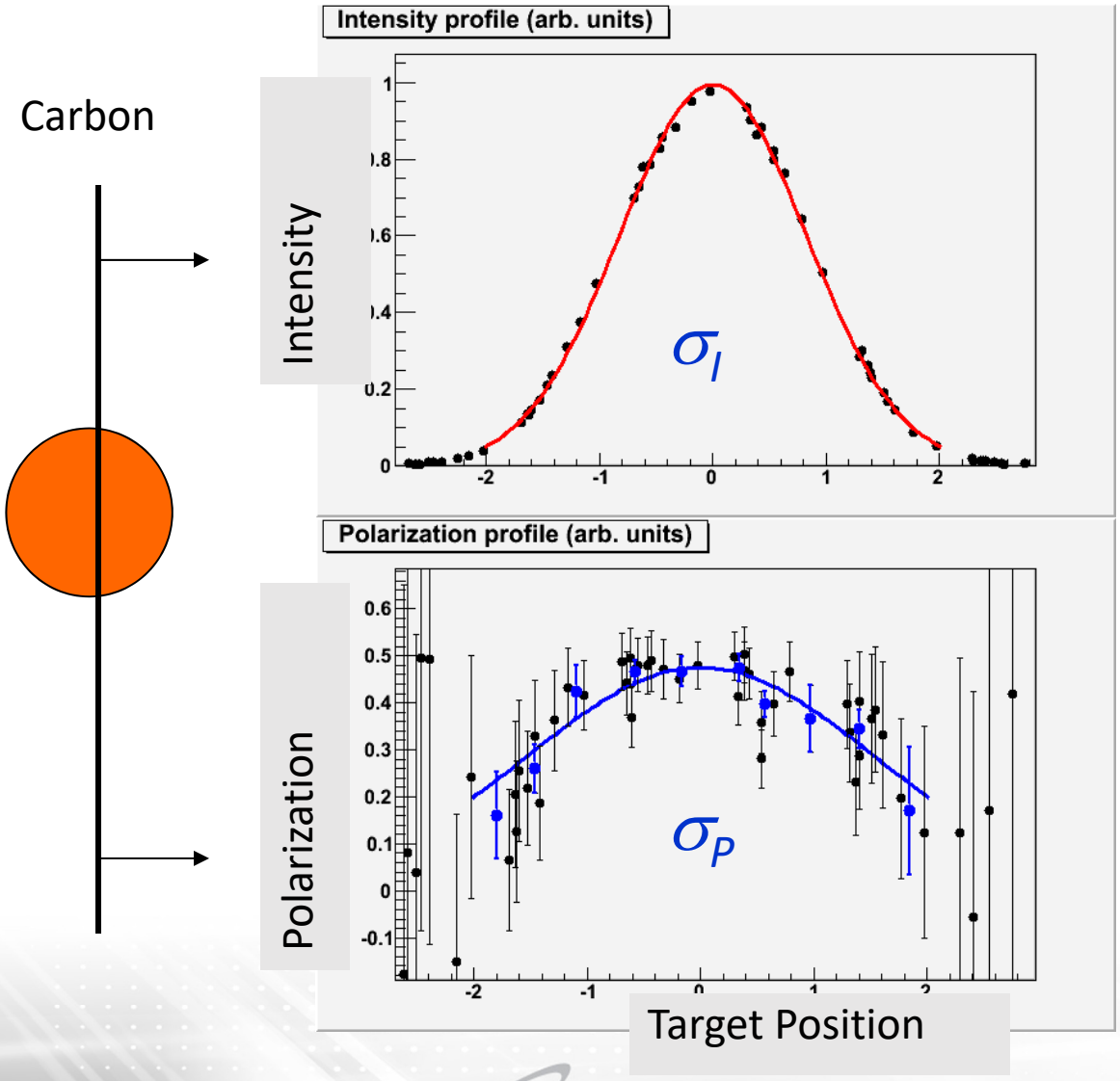
Snake resonances:

$$\nu_y = \frac{2n+1}{2m}$$

Possible Contributions of Polarization Lifetime

- The snake resonance at Q_y=7/10 is the main source of polarization deterioration at store.
- The direct effect on spin motion due to beam-beam force is negligible but the beam-beam tune spread can push the beam towards the snake resonance. E-lens has been used to mitigate this problem with increased bunch intensity in run15.
- There is impact of local orbit at spin rotators on the store polarization lifetime. In addition to the spin tune shift due to vertical separation bump at IP where spin is longitudinal, the horizontal IP angles can also produce a resonance driving term. This can potentially cause depolarization during store.

Profiles Example

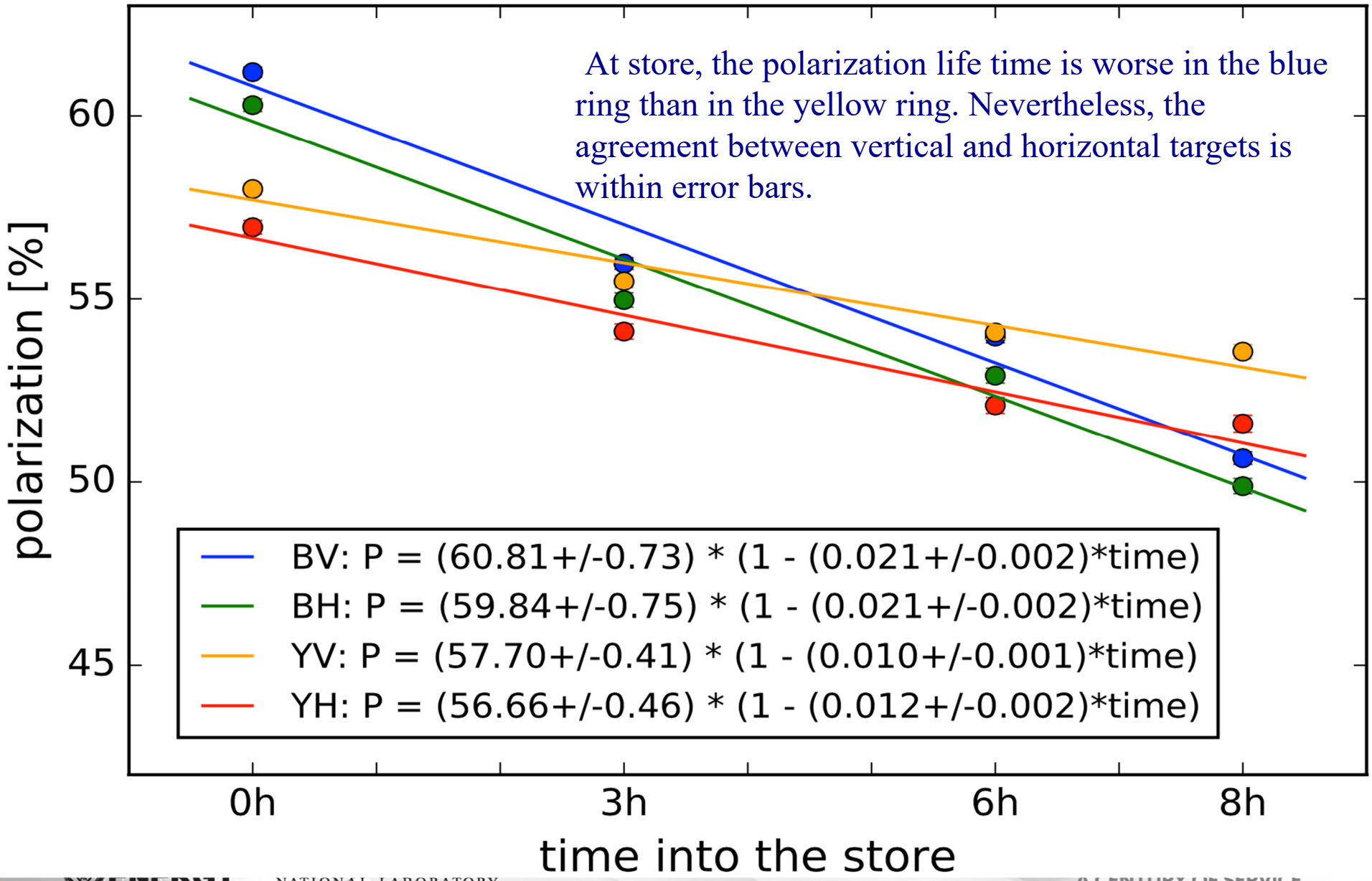


Can the contribution from emittance growth and stronger polarization profile be separated?

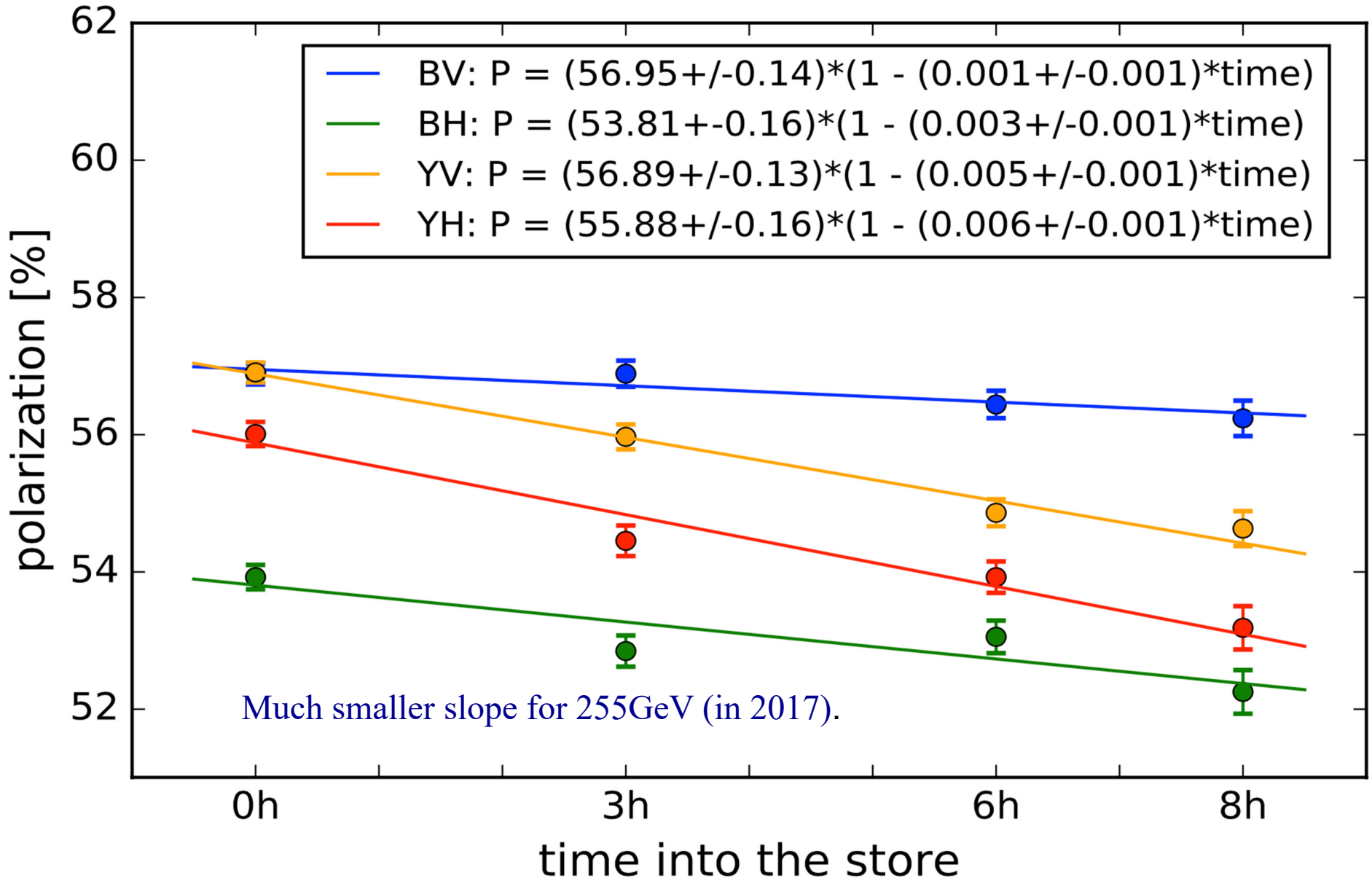
Analysis Method

- The measurements with the two polarimeters were taken at 0, 3, 6, and 8 hours from the start of the store. By combining measurements from many stores at different times, the polarization decay and polarization profile growth information can be derived.
- The RHIC transverse emittance was measured periodically at store by IPM throughput the length of the store. There is a slow but steady growth in both planes. Large emittance means larger depolarizing resonance strength, so contribution of polarization loss due to emittance growth is expected. Since we have both the polarization decay rate and emittance growth rate, it is possible to separate the contribution of polarization losses from emittance growth and lattice effect.

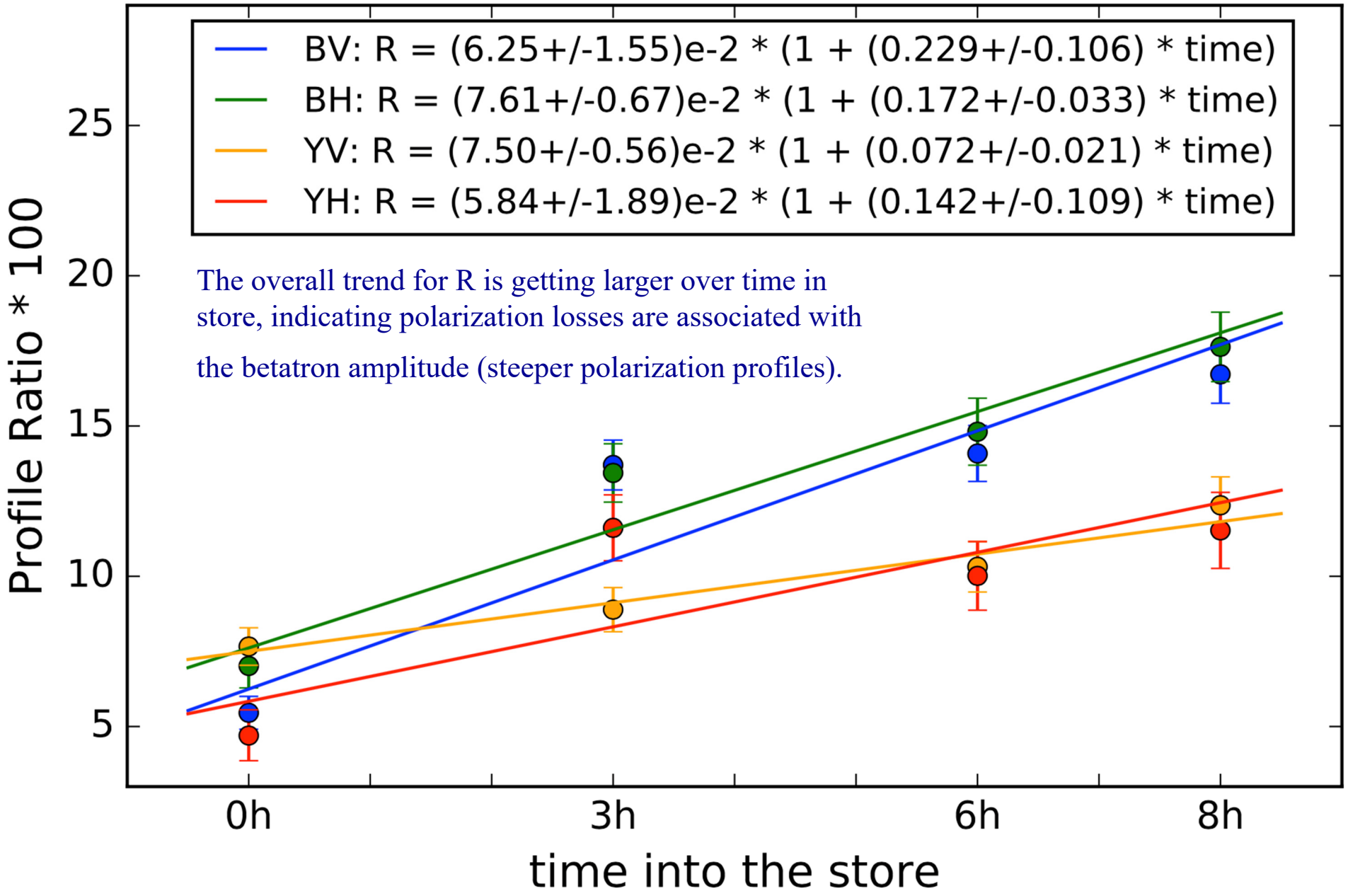
Polarization vs Time at 100 GeV Stores



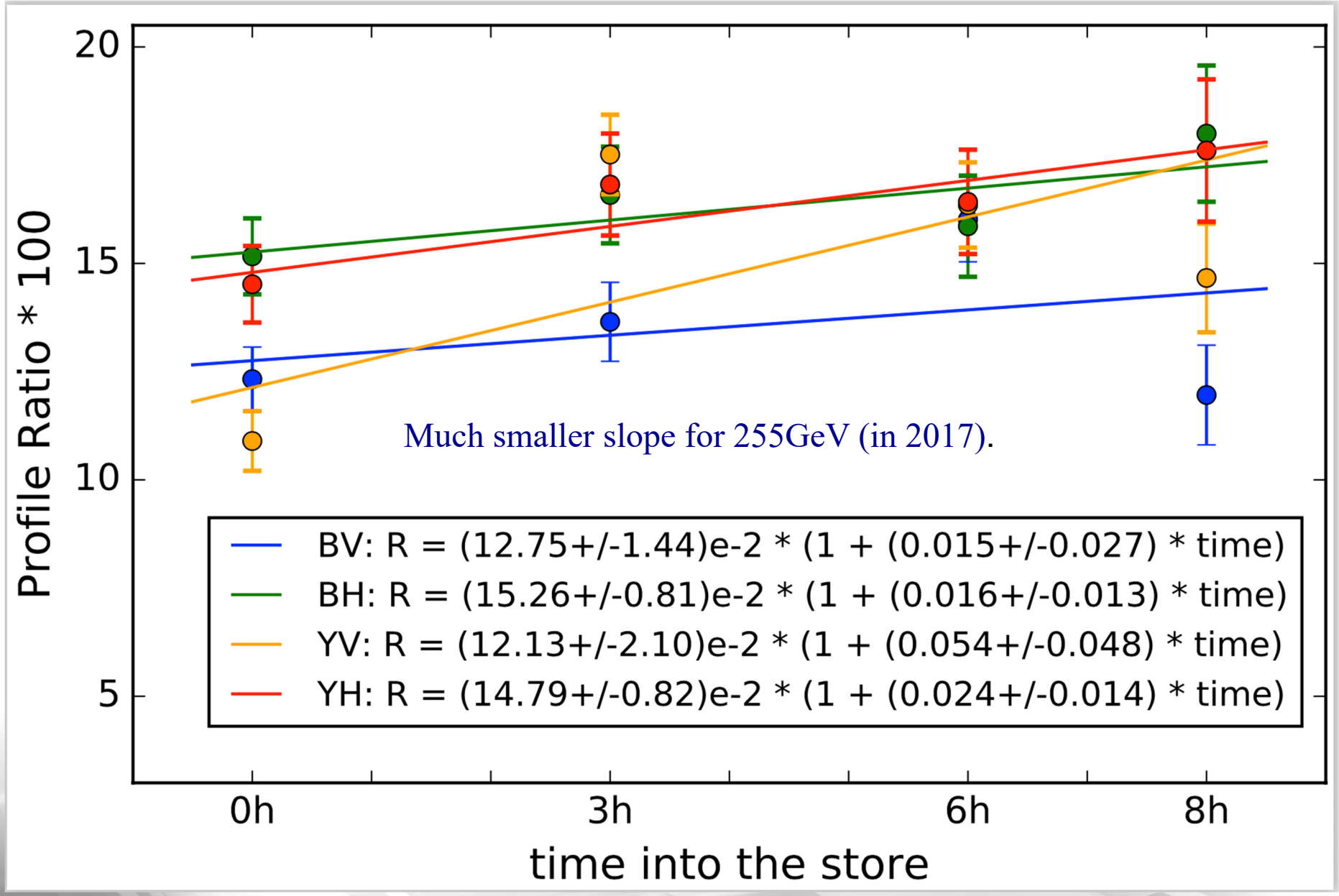
Polarization vs Time at 255 GeV Stores



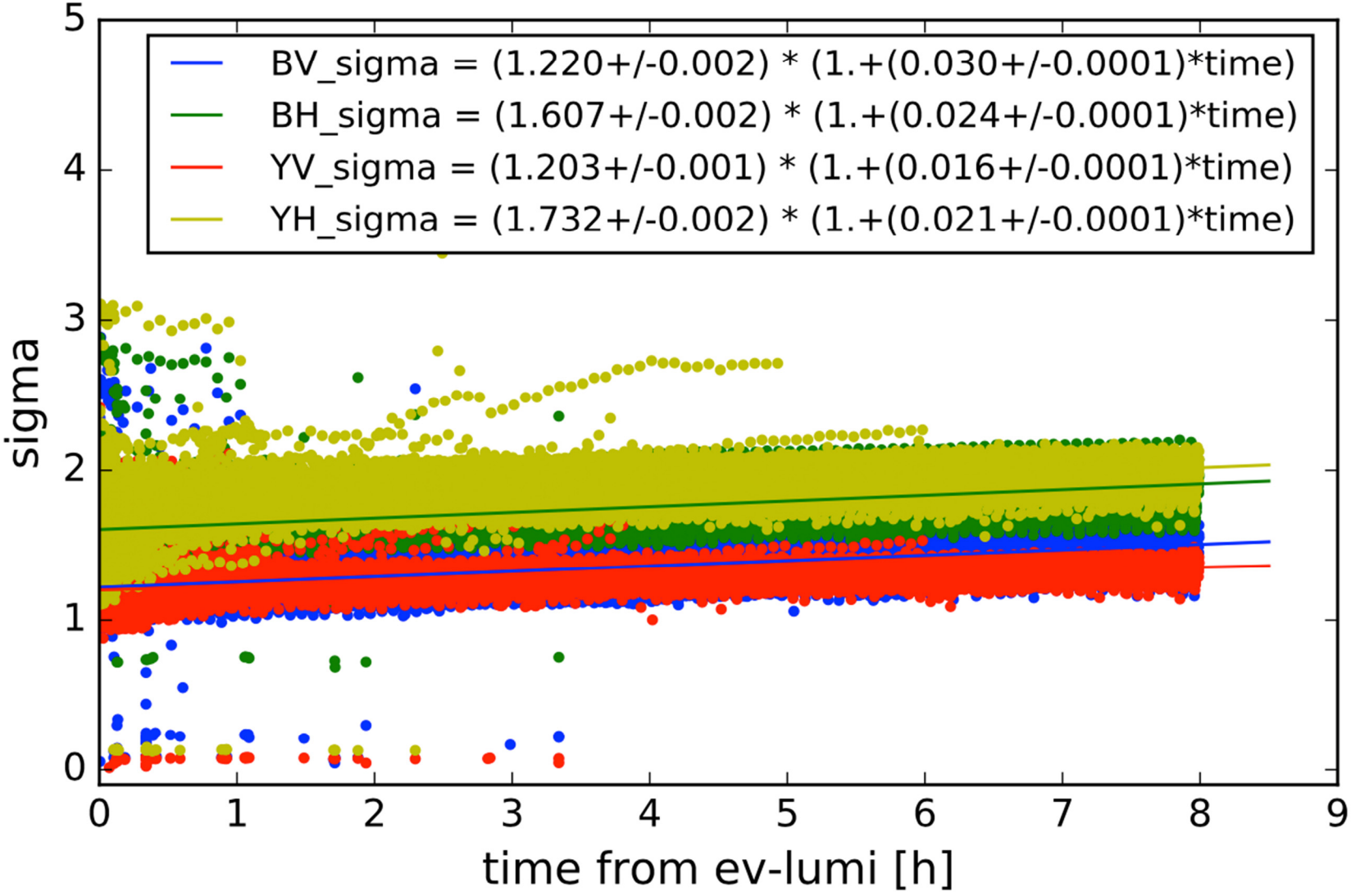
Polarization Profiles vs Time at 100 GeV Stores



Polarization Profile vs Time at 255 GeV Stores



IPM Beam σ vs Time at 100 GeV Stores



Effects of Emittance Growth & Stronger Resonance

- With emittance growth rate known, the effects of emittance growth and stronger depolarizing resonance can be separated.
- The round Gaussian distribution is assumed for both beam and polarization profiles.

$$R \approx R_0(1 + a_r t) \approx [\frac{\sigma_{b0}(1 + a_b t)}{\sigma_{p0}(1 - a_p t)}]^2$$

$$(1 - a_p t) = \frac{(1 + a_b t)}{\sqrt{(1 + a_r t)}} \approx 1 + (a_b - \frac{a_r}{2})t$$

$$a_p = -(a_b - \frac{a_r}{2})$$

Slopes of Beam and Polarization Profiles

	a_r	$2a_b$	$2a_p$
B(100)	0.177±0.031	0.054±0.002	0.123± 0.031
Y(100)	0.074±0.021	0.037±0.002	0.037±0.021
B(255)	0.016±0.009	0.022±0.005	-0.006± 0.010
Y(255)	0.026±0.013	0.036±0.002	-0.019±0.014

- The round Gaussian distribution is assumed for both beam and polarization profiles.
- With emittance growth rate known, the effects of emittance growth and stronger depolarizing resonance can be separated.
- For 255GeV, the lattice design reduced the resonance strength at store. Spin rotator off also helped.

Summary

- The polarization decay and polarization profile development (R value) during store were analyzed by combining polarization measurements from many stores.
- The polarization decay and polarization evolution are consistent from vertical and horizontal targets.
- The time dependence of these quantities provides source information about the polarization loss. Besides the obvious contribution from transverse emittance growth during store, the additional polarization loss is related to the lattice and working point. The difference among various lattices implies that the effect can be mitigated by a careful selection of working point and lattice design.
- Further simulation with various realistic lattices can be compared with these results to understand the polarization loss mechanism with the emittance growth effect excluded.