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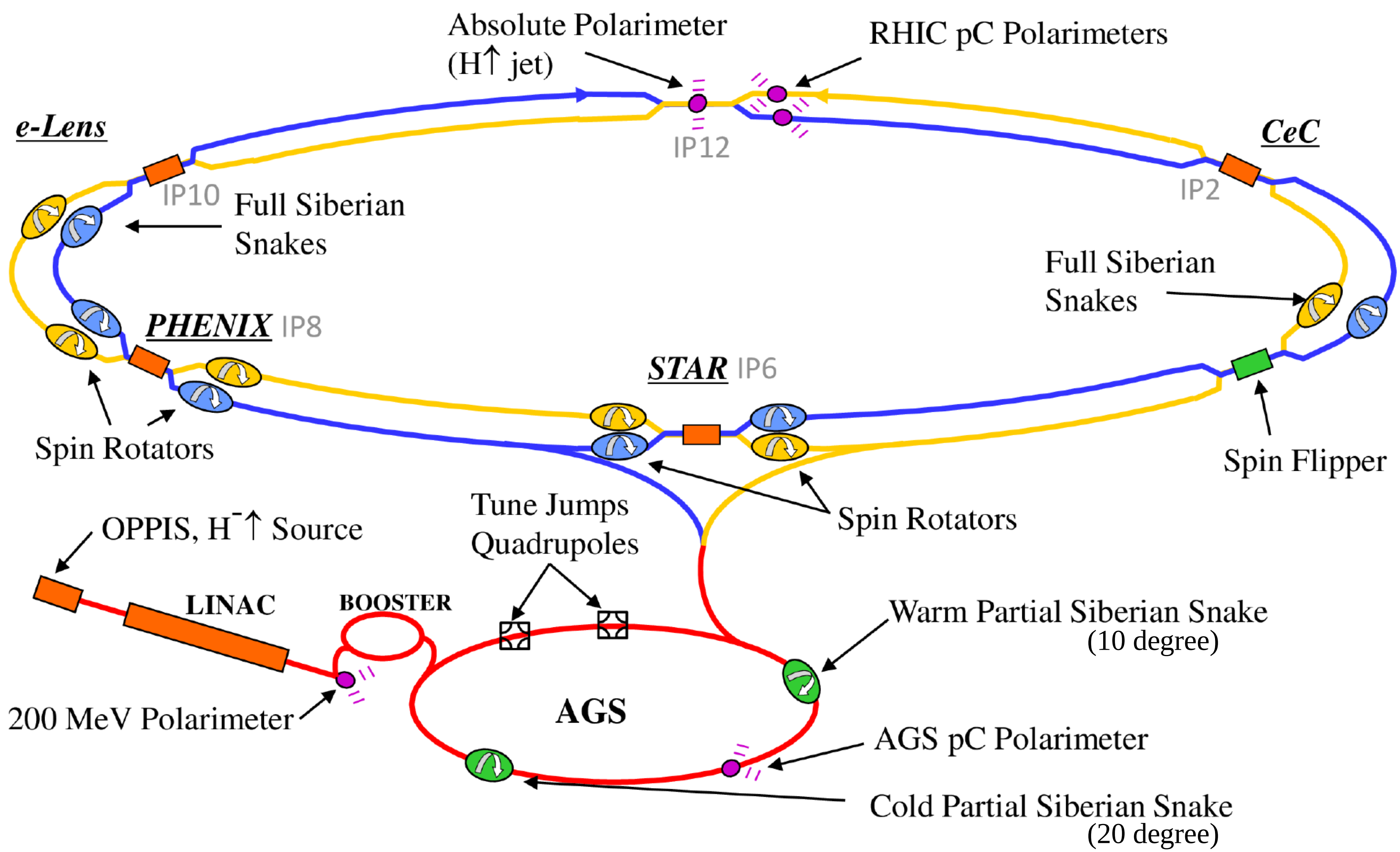
Exploring a Possible Origin of an Abnormal $10\sim15$ degree Spin Tilt Observed at RHIC Polarimeters

For the collaboration
François Méot
Collider-Accelerator Department
Brookhaven National Laboratory

Contents

1 ACCELERATION OF POLARIZED PROTONS AT RHIC



◇ **Polarization measurements in RHIC monitor**

- polarization loss due to snake resonances during ramp (≈ 300 s to 250 GeV),

- gradual polarization loss during the typical 8 hours physics store.

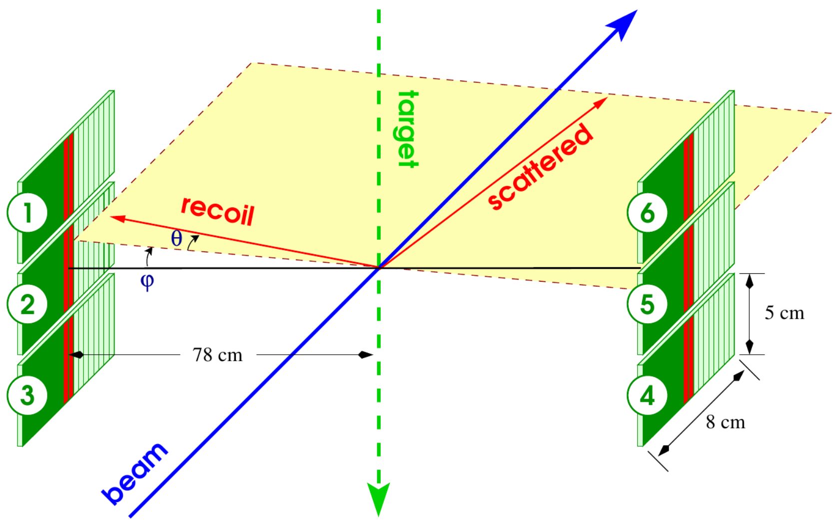
POLARIZATION MEASUREMENTS AT RHIC

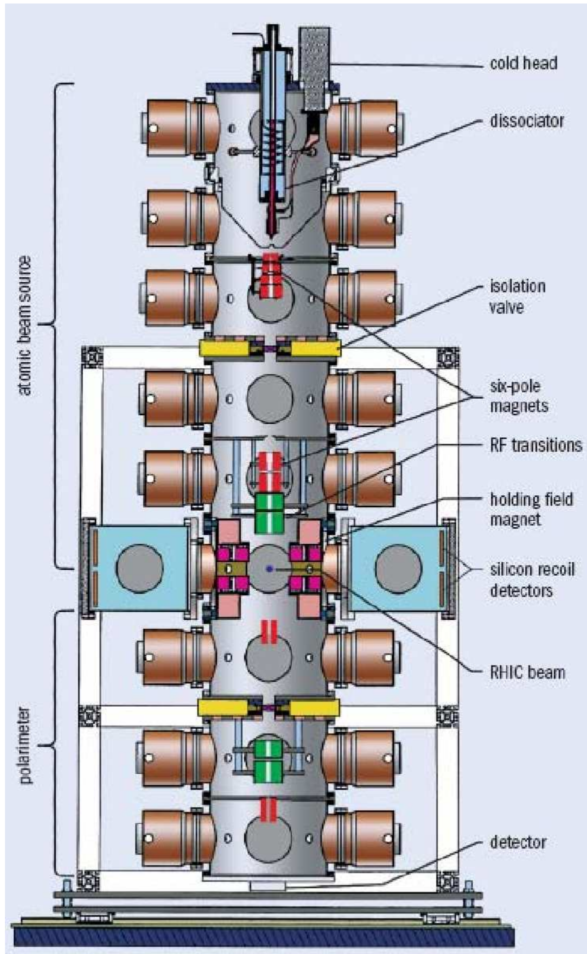
- **Two different devices ensure polarization measurements in RHIC :**

(i) A polarized hydrogen jet target :

◇ **Measures P_Y only (1 pair of detectors)**

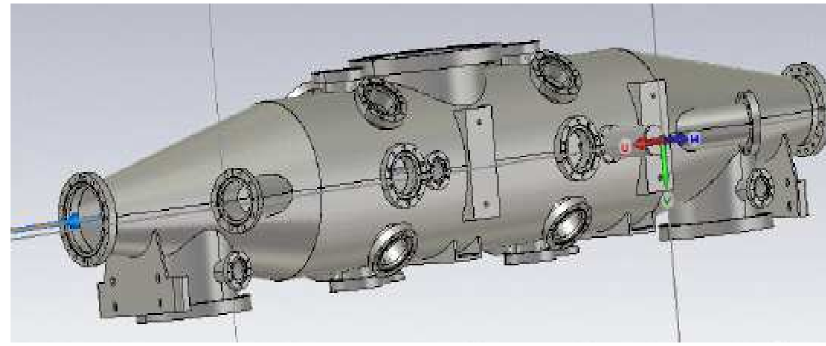
◇ **Provides calibration for the pC polarimeters (and to the physics program), accuracy $\sigma_{\frac{\Delta P}{P}} \approx$2-3%.**





(ii) A fast carbon target pC polarimeter :

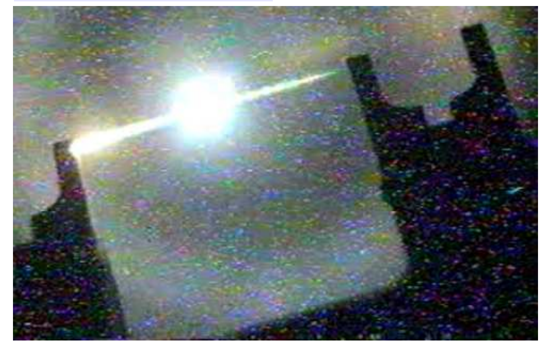
pC polarimeter chamber in RHIC (1 per ring)
with view- and mounting-ports



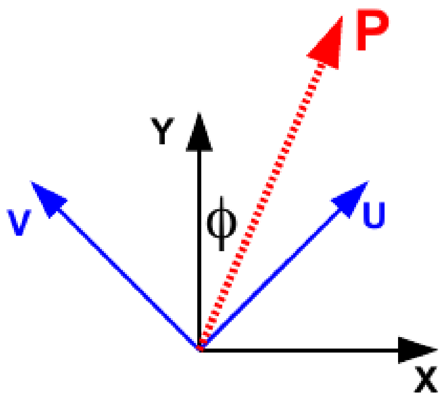
◇ **beam polarization in ∼a minute**

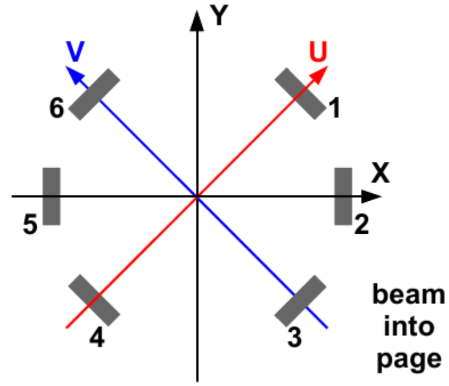
◇ **target : ultra-thin carbon ribbon swept through the beam**

pC carbon target



◇ **Three pairs of detectors at 90^o and 45^o for measurement of P_Y (vertical) and P_X (radial) polarization components**





◇ P_Y **is measured** $\begin{cases} \textbf{by 2-5 pair,} \\ \textbf{as } (P_U + P_V)\cos(45\text{deg.}), \textbf{ with 1-4 pair } (\mathrm{P_V}) \textbf{and 3-6 pair} (\mathrm{P_U}) \end{cases}$

◇ **1-4 and 3-6 pairs provide vertical tilt ϕ of (x,y) plane polarization component :**

$$\tan(\phi) = \frac{P_X}{P_Y} = \frac{P_U - P_V}{P_U + P_V}$$

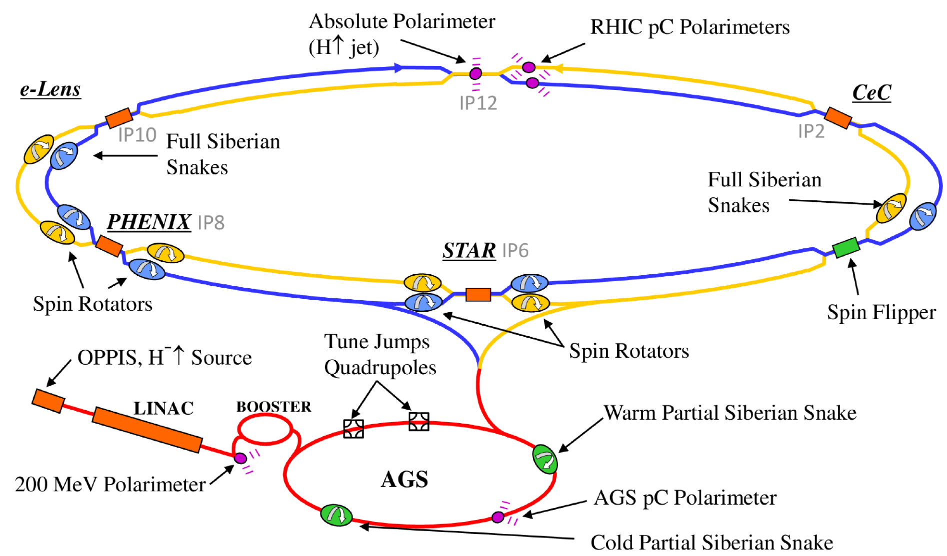
A SUMMARY OF POLARIZATION MEASUREMENTS

- **Polarization measurements at pC polarimeters are performed**
  - ◇ **shortly after injection, before the ramp, E = 23.8 GeV**
  - ◇ **at store** { **one before collision (one more after rotator ramp if any)** / **then every 2-3 hours during collision**

(measurement induces < 0.5% beam loss, and physics run has to stop)

Run #	E [GeV]	MEASURED TILT ANGLE AT pC (degree) Blue ring	Yellow ring	
RUN 11 - transverse polarization at IPs				
	injection	– 0.92 –		
	250	-2.88	-1.07	*No tilt observed at Run 11*
RUN 12 - transverse polarization at IPs				
	injection	– 0.86 –		
	100	3.05	-0.97	
	255	13.8	-6.49	*Tilt observed at 255 GeV from Run 12 on*
RUN 13 - longitudinal polarization at IPs				
	injection	– 1.25 –		
	255	13.28 $\sim$ 16.14	-9.17 $\sim$ -8.40	*Interval includes pre/post rotator ramp, pre/post Run12 lattice...*
RUN 15 - Periods 1, 3 longitudinal / Period 2 transverse polarization at IPs				
	injection	0.40 $\sim$ 1.65	1.47 $\sim$ 3.20	
	100	3.72 $\sim$ 4.86	1.27 $\sim$ 3.20	

• Crucial point : What is the spin tilt at H-jet, located at IP12 ?



◇ **To date it has been assumed H-jet measures polarization magnitude $|\vec{P}|$, in calibrating pC polarimeters.**

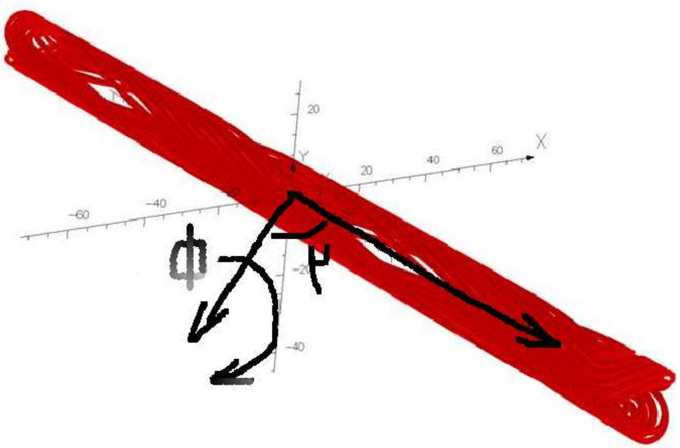
◇ **If there is a spin tilt $\phi \neq 0$ at IP12, then measured $|\vec{P}|$ is affected by a factor $\cos(\phi)$, e.g., main tilts measured during Run13 / 255 GeV :**

- **Yellow at store: ϕ = -9deg $\rightarrow \cos(\phi) = 0.99$, 1% scale shift**
- **Blue at store: ϕ = +16deg $\rightarrow \cos(\phi) = 0.96$, 4% scale shift,**

***significant*, need to account for in polarization measurements...**

3 PERTURBATION ON SNAKE ANGLES

• Reminder



◇ **RHIC snake is a doublet of paired helices with central vertical symmetry**

⇒ { **does not introduce orbit defect,**
precession axis is in median plane.

◇ **fields B_1 and B_2 in respectively the outer and inner helix in a pair can be controlled**

⇒ { **precession axis is at $\mu = \pm 45^o$,**
$\phi = 180^o$ spin rotation ("full snake").

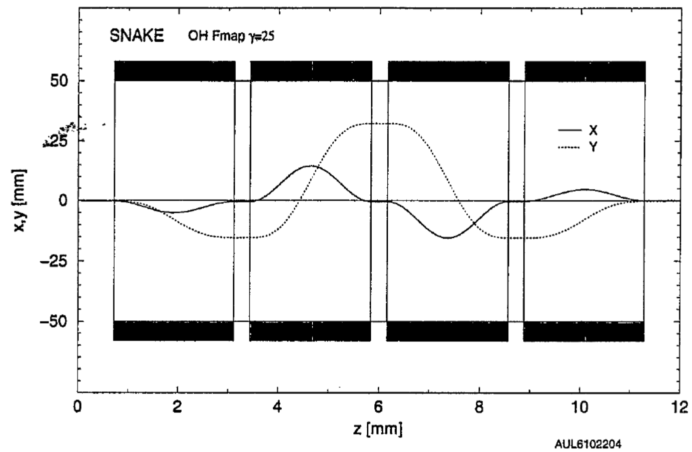


Figure 6: Snake orbit components. $\gamma = 25$. OH fieldmap.

• **Principle of these investigations** **regarding the**

effect errors on the spin rotation angles $\phi_1,\ \phi_2$ in RHIC snakes :

$\diamond$ (ϕ_1, ϕ_2) **scans are performed,**

both angles are varied over $\pm 20^o$ centered on the nominal $\phi_{1,2} = 180^o$ (spin flip).

$\diamond$ **These (ϕ_1, ϕ_2) scans are repeated to include various additional perturbations :**

- defect closed orbit with various amplitudes,

- errors on the orientation of the spin precession axis μ_1, μ_2 in snakes 1 and 2,

- vertical orbit separation at non-intersecting IRs

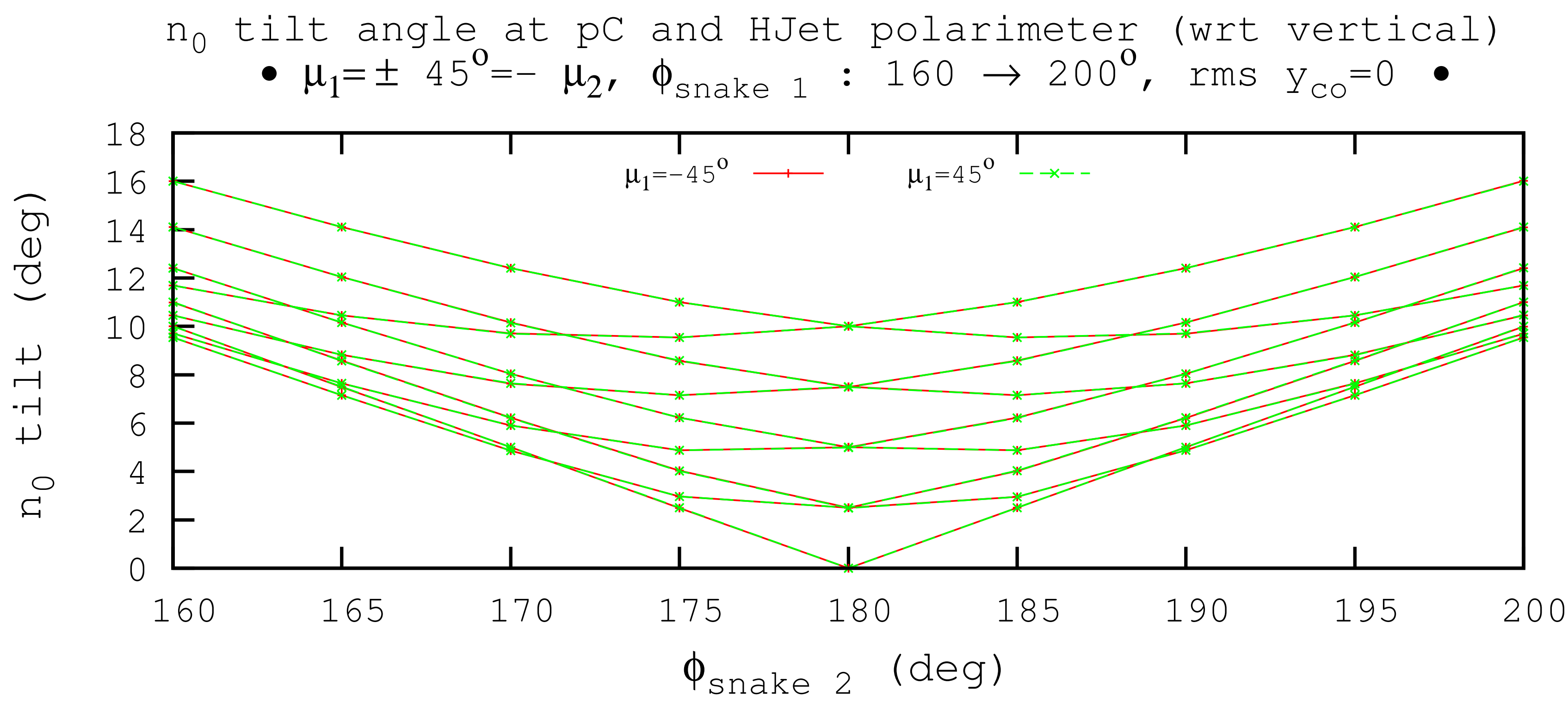
- etc.

• **A first example : ideal RHIC optics, 255 GeV, zero vertical orbit**

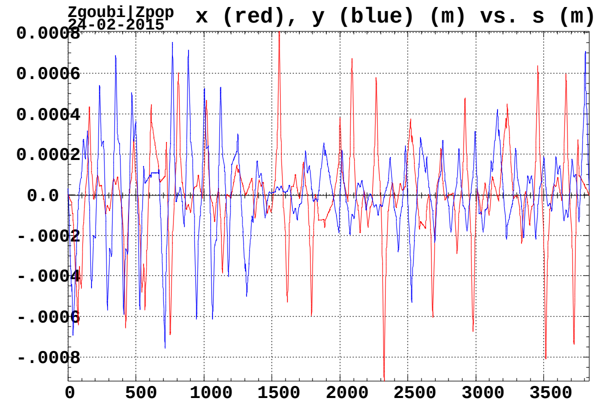
◇ **Because the vertical orbit is zero,**

the vertical tilt angle of $\vec{n}_0$ is the same at pC and HJet polarimeters ;

(Note that $\vec{n}_0$ azimuth is different, due to D0 and DX separation dipoles between both.)



• **Second example : case of a (large) 0.26 mm *rms* vertical orbit**



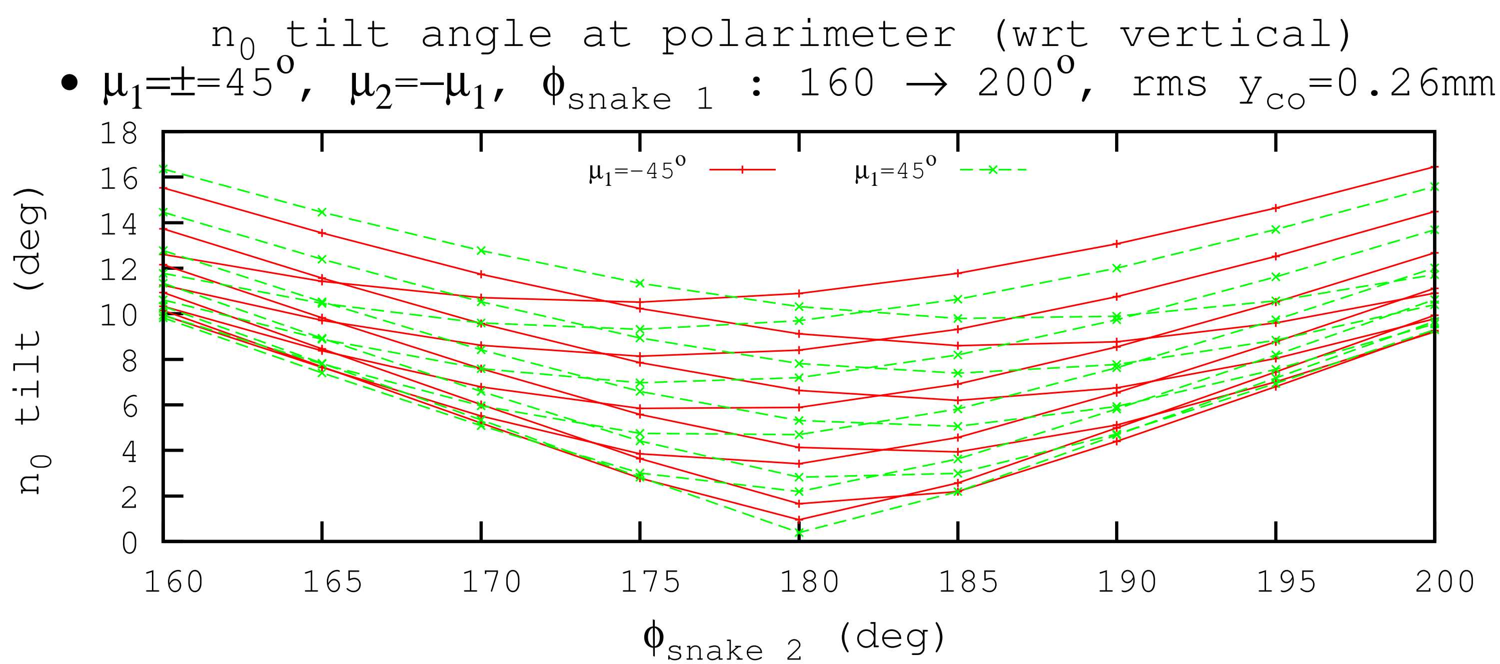
◇ **Such large vertical orbit is**

about 10 times the regular one ($25\ \mu$m *rms*).

◇ **Similar $\vec{n}_0$ tilts result at pC and HJet polarimeters,**

since the vertical orbit only induces small, random, $\vec{B}_x$

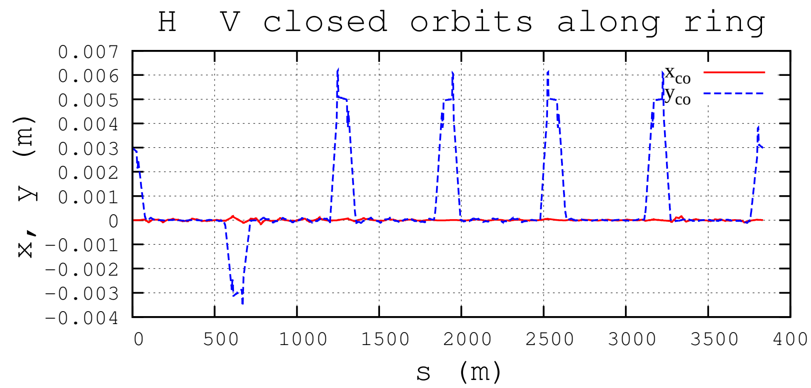
(hence, not much effect of the low-β quadrupoles, located between pC and HJet).



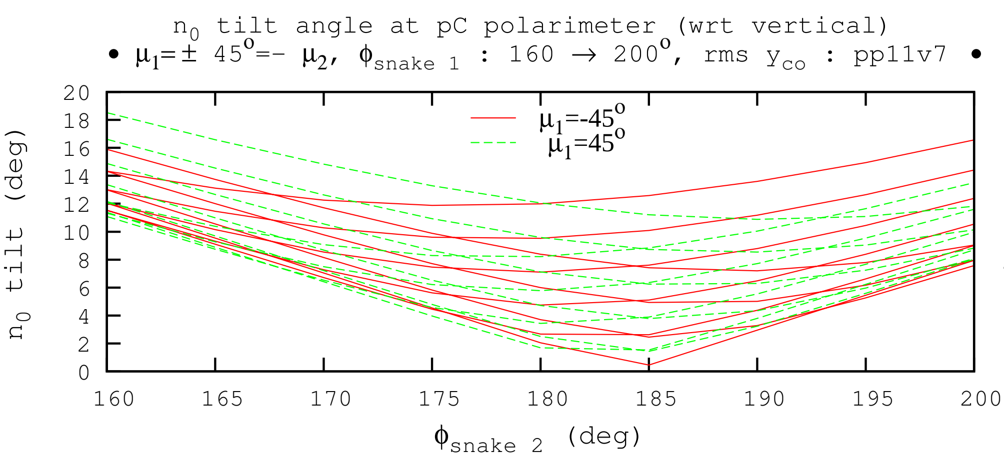
• A third example : vertical separation bumps at all IPs

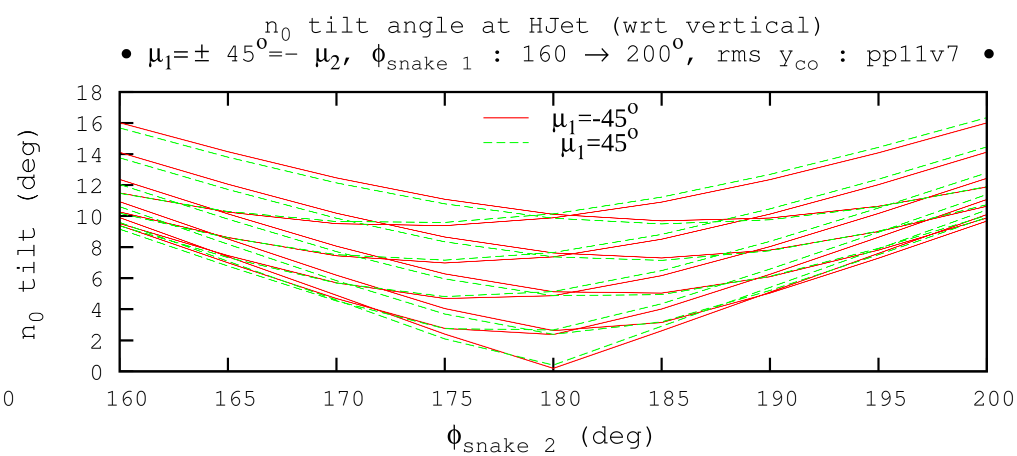
◇ **This is the configuration at end of ramp, before going to collision.**

◇ **Random orbit here is regular 25μm *rms*.**

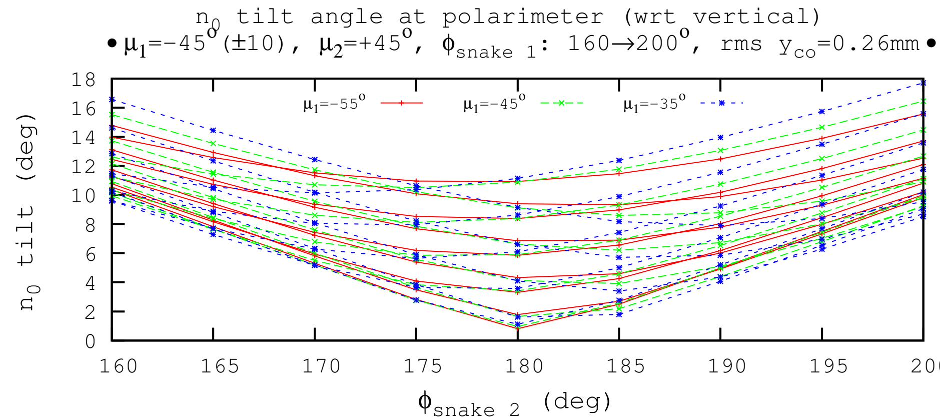


◇ **The low-β quadrupole triplet between HJet and pC polarimeters causes slightly different $\vec{n}_0$ tilt at pC and HJet.**



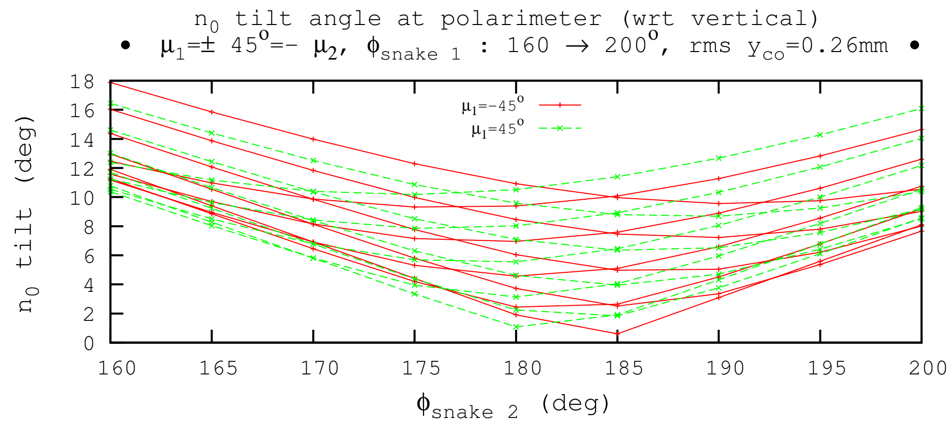


AND MORE :



• A small error on μ_1

◇ $\mu_1 = -45 \mp 10$ **deg,** $\mu_2 = +45$ **deg.**



• beam energy 100 GeV

◇ **0.26 mm *rms* vertical orbit**

• At injection, 23.8 GeV

◇ **0.26 mm *rms* vertical orbit** $\rightarrow$ **similar outcomes**

• CONCLUSION TO THESE SPIN $\vec{n}_0$ TRACKING SIMULATIONS :

• All different conditions explored (closed orbit, perturbations on μ, etc.)

◇ yield similar $\vec{n}_0$ tilt excursions over 180±20^o scans of $\phi_1,\ \phi_2$

◇ namely, at both pC and at HJet polarimeters :

- $\vec{n}_0$ tilt angle ~ 10 degree for ±10 deg. error on the snake angles ϕ_1, ϕ_2

- and this, independent of energy : 250 GeV, 100 GeV or injection energy 23.8 GeV.

4 PLANS FOR FUTURE

- **Measurements are planned in Run17. It will take 3 stores for $\pm 1^o$ accuracy on measurement of $\vec{n}_0$ tilt at pC polarimeters.**

  ◇ **We will re-measure spin tilt at 250 GeV (case of Run 11) and 255 GeV (case of Run 12, 13, 15)**

- **We will re-visit RHIC snakes magnetic field maps, and snake settings**

  ◇ **we plan to produce a 3-D OPERA map of the 4-helix magnet, and**

  - to review the transfer functions from coil currents to helix magnetic fields $B_1,\ B_2$ to spin rotation,

  - to further investigate spin $\vec{n}_0$ based on tracking simulations in RHIC using the OPERA field maps of the two snakes.

THANK YOU

References

[1] W. Schmidke BNL/C-AD spin meeting, for the polarimetry group 25.02.15.

[2] RHIC design report, Chap. 4.

[3] PAC and IPAC conferences

[4] Optimization of spin angles from a helix field map, A. Luccio, Spin Note AGS/RHIC/SN 42, BNL, 1996.

[5] N. Okamura et al., AGS/RHIC SN 030 (1996).

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