Large Piwinski Angle MD

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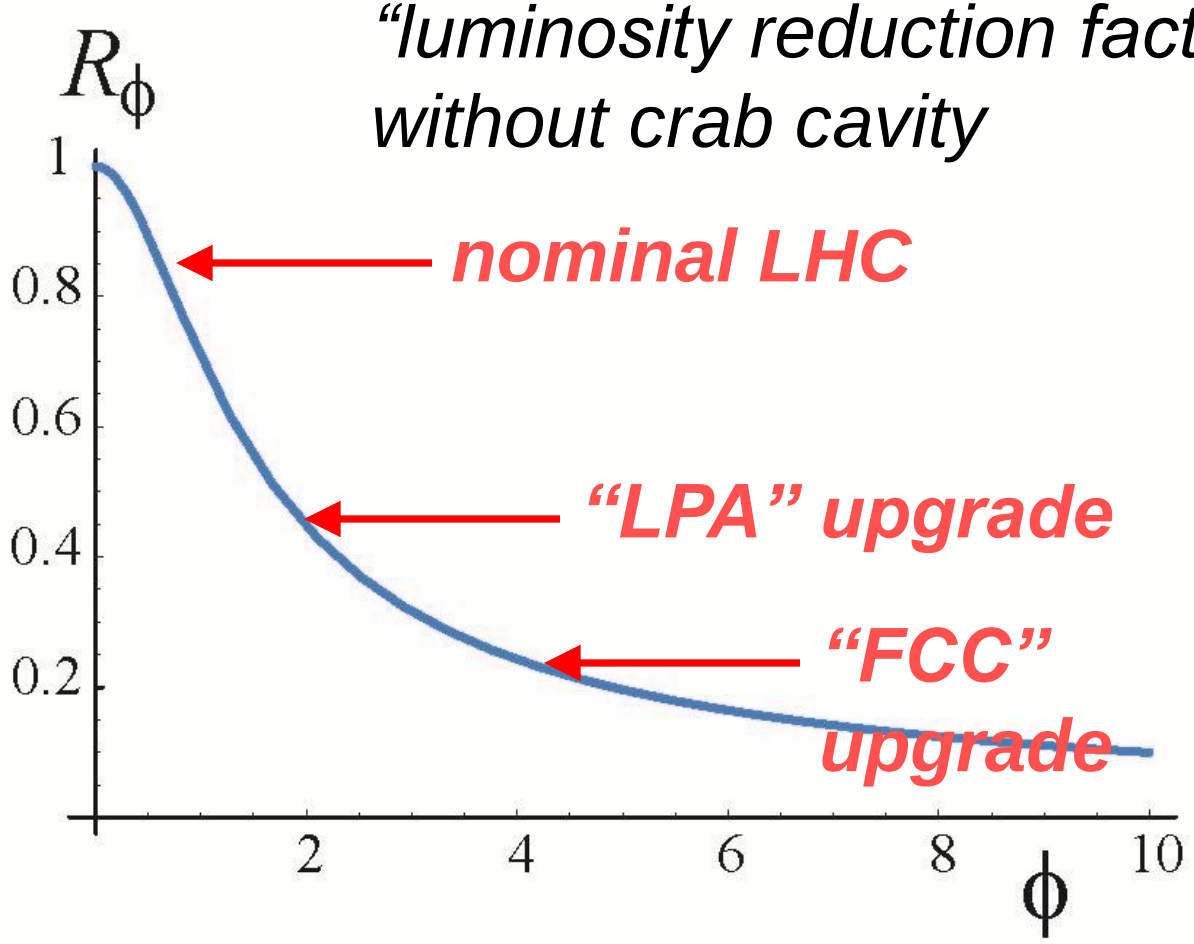
Piwinski angle

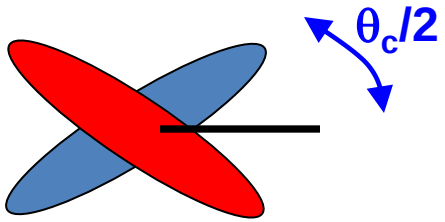
$$R_\phi = \frac{1}{\sqrt{1+\phi^2}}; \quad \phi \equiv \frac{\theta_c \sigma_z}{2\sigma_x}$$

primary motivation for HL-LHC & LHeC

"Piwinski angle"

"luminosity reduction factor" without crab cavity





effective beam size:

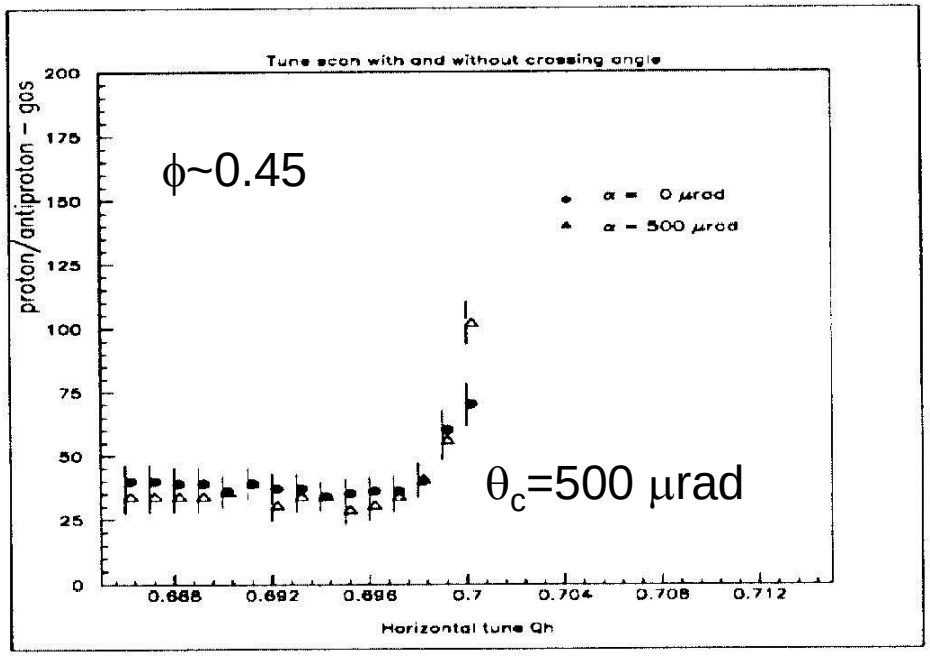
$\sigma^*_{x,eff} \approx \sigma_x^*/R_\phi$

Piwinski angle:

- geometric overlap
- tune shift
- syn.beta resonances
- symmetry breaking

motivation

- for e+e- colliders crossing angle could lead to large reduction in beam-beam limit & luminosity
  (DORIS-I→ ***"Piwinski angle"*** ϕ, KEKB → crab cavities)
- little is known about hadron collider beam-beam limit with crossing angle; RHIC & Tevatron: head-on collisions
- the only controlled experiment was done at SppbarS
- nominal LHC was pushed to ϕ**~0.64**
- ϕ will futher increase for smaller-than-design emittance
- HL-LHC scenarios consider ϕ up to 2.5
- beam-beam limits experiments so far were done for head-on collisions or very small Piwinski angle

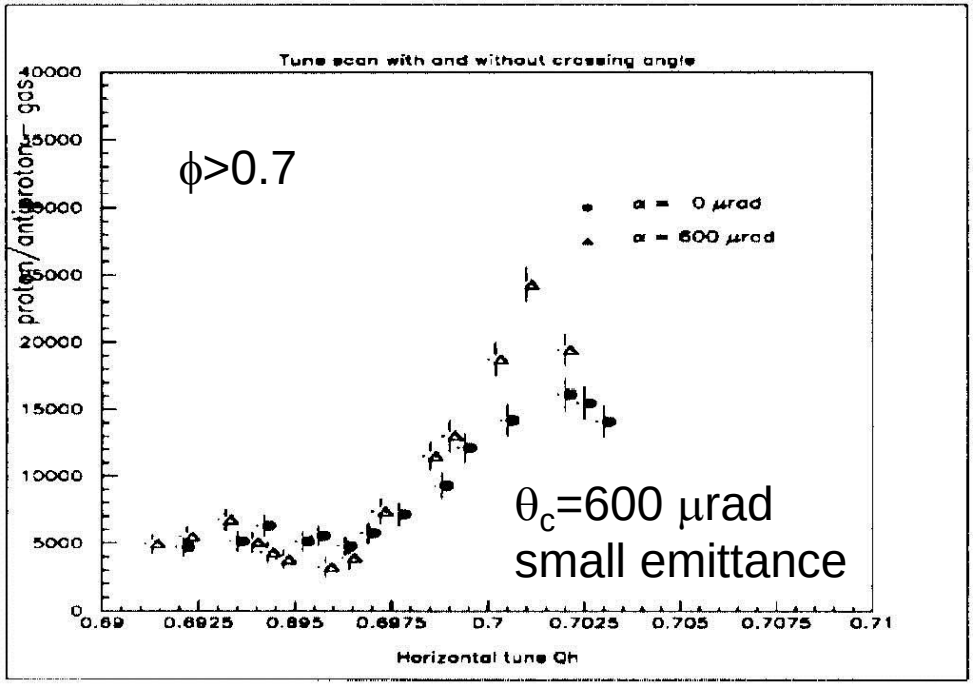


historical experiments at SPS collider

K. Cornelis, W. Herr, M. Meddahi, "Proton Antiproton Collisions at a Finite Crossing Angle in the SPS", PAC91 San Francisco

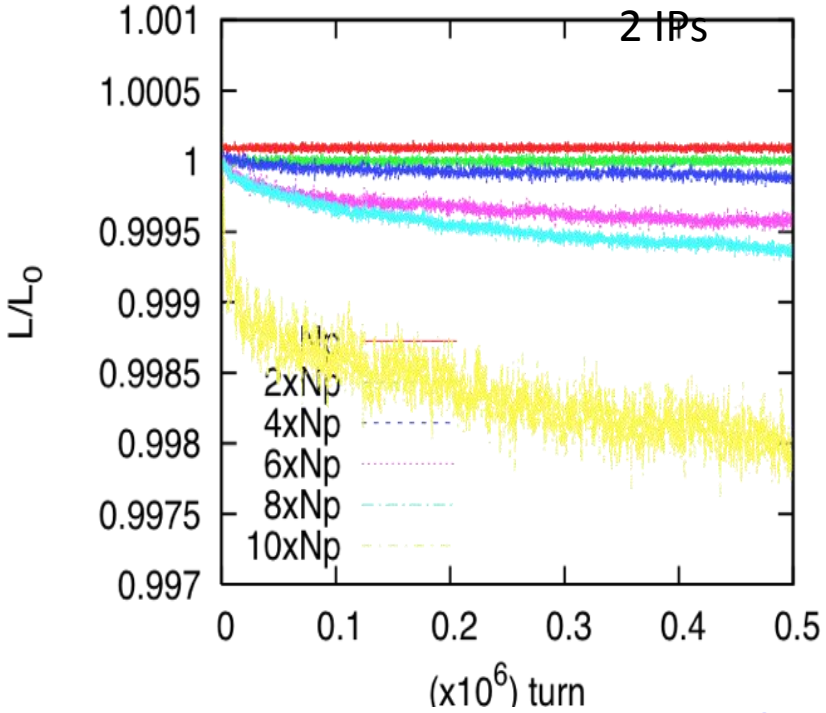
SPS tests up to ϕ>0.7 showed some additional beam-beam effect

present nominal LHC: ϕ~0.64,
ATS upgrade: ϕ~2.5!



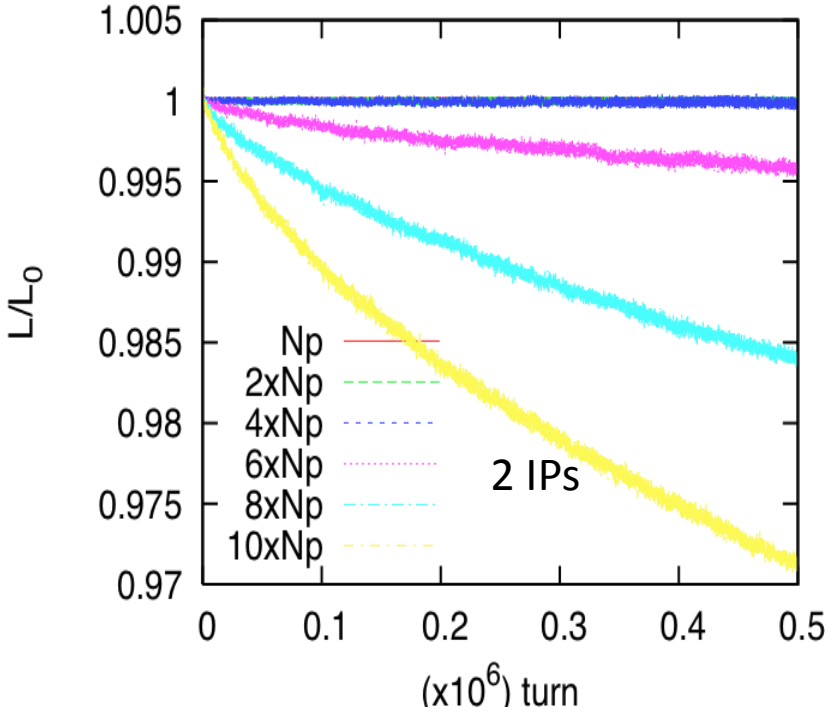
simulations for nominal LHC with higher bunch charge

no crossing angle



collisions with 285 μrad crossing angle

K. Ohmi



simulated luminosity lifetime with no crossing angle is 10 times better than with 285 μrad angle

(ϕ≈0.65, β^*=0.55m, $\gamma\varepsilon$=3.75 μm, E=7 TeV)

MD plan

- **transient losses going into collision, beam lifetime and luminosity lifetime for large and zero Piwinski angle**
- beam parameters that correspond to $\xi \geq 0.03$ for $\theta = 0$
- **injection energy, collision tunes**
- 2 **or 3 ultimate low-emittance bunches per beam**
- 3 bunches would be at/above **safe beam limit** (5e11)
- one bunch of each **beam collides in IP1, IP5, (IP2) and IP8**
- **Piwinski angle is varied** by changing θ at maximum bunch length longit. blow up in SPS and injected into a 3 MV RF voltage in LHC to obtain 4sigma_z~1.6 ns (times c)
- **nominal & zero spectrometer strength in IP8**
- **orbit correction** when changing spectrometer strength
- beams also have to be brought into **collision**
- **TCT adjustment** needed in IP8 (& IP2)?

MD table - details

Beam energy [GeV]	450
Optics (injection, squeezed, special)	Nominal injection optics (beta*=10 m in 8)
Bunch intensity [#p, #ions]	1.7e11 protons, 1.0-1.2 micron emittance
Number of bunches	two per beam with one bunch colliding in both IP 1+5 and 8, and the other bunch colliding only in IP8
Transv. emittance [m rad]	1.0-1.2 micron (as low as possible)
Bunch length [ns @ 4σ]	1.6 ns
Optics change [yes/no]	No
Orbit change [yes/no]	Yes, up to 2 mrad half crossing angle change in IP8
Collimation change [yes/no]	Change of TCT in IP8 (and IP2)?

Simulations of the LPA MD

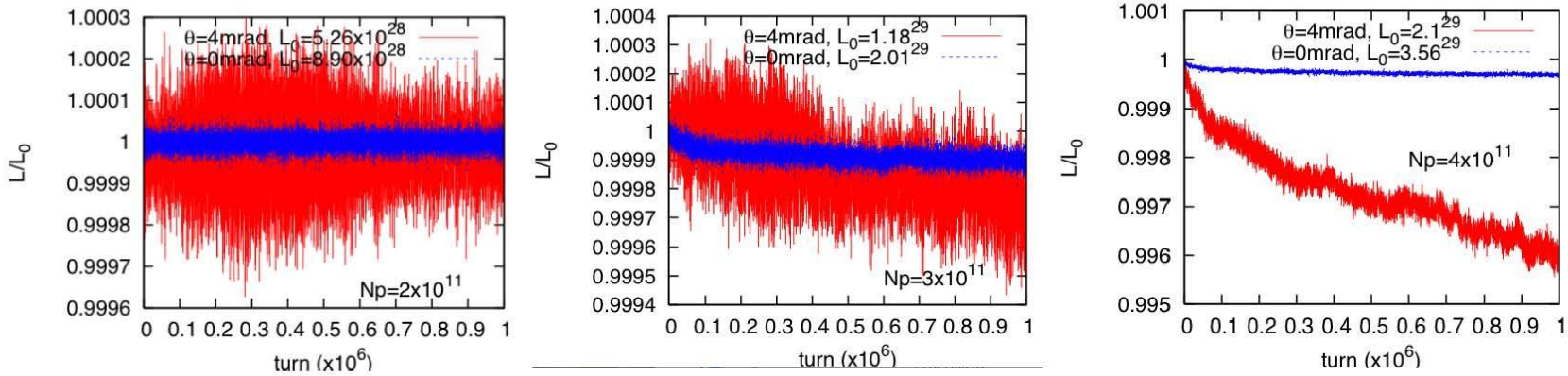
Parameters

- E=450 GeV, Np=3×10^{11}, 2×10^{11}, 1.2×10^{11}.
- σ_z=1.6ns/4=0.12m, $\sigma_\delta=3\times10^{-4}$.
- $\beta_z=\sigma_z/\sigma_\delta$=400m, ν_s=0.0034.
- β^*=10m (3m). $\gamma\varepsilon$=1.5, 2.0×10^{-6}.
- VRF=3 MV (400MHz). $\eta_p=3.18\times10^{-4}$
- IP8 θ(half)=2mrad, $\theta\sigma_z/\sigma_x$=1.175
- IP2 θ(half)=1mrad, $\theta\sigma_z/\sigma_x$=0.588

K. Ohmi, KEK

Weak-strong, IP2&8

10^9turn/day, $\Delta L/L_0 = 10^{-3}/10^6$ is visible level.



- proton intensity x1,x1.5, x2.
- Np=4x1011 shows clear difference in luminosity degradation. ***2 IPs not feasible!***
- Fluctuation is larger in crossing collision.

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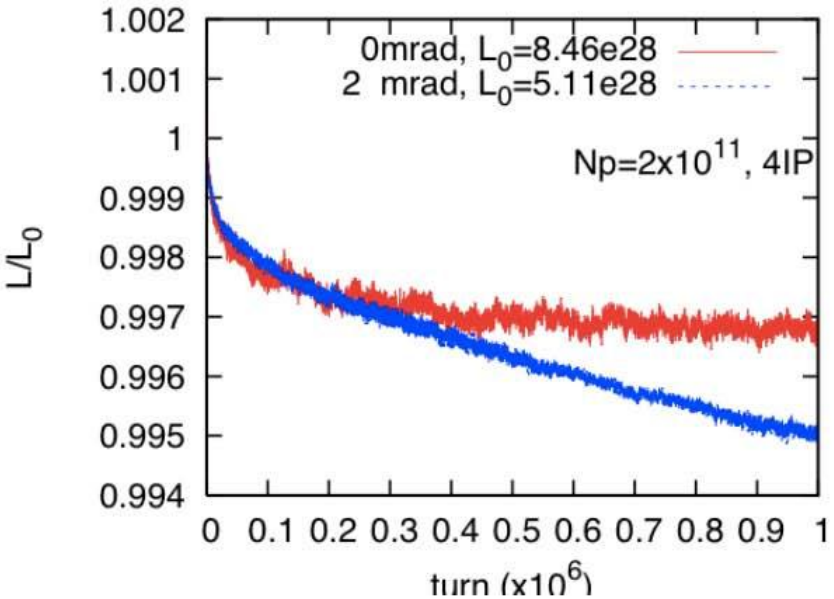
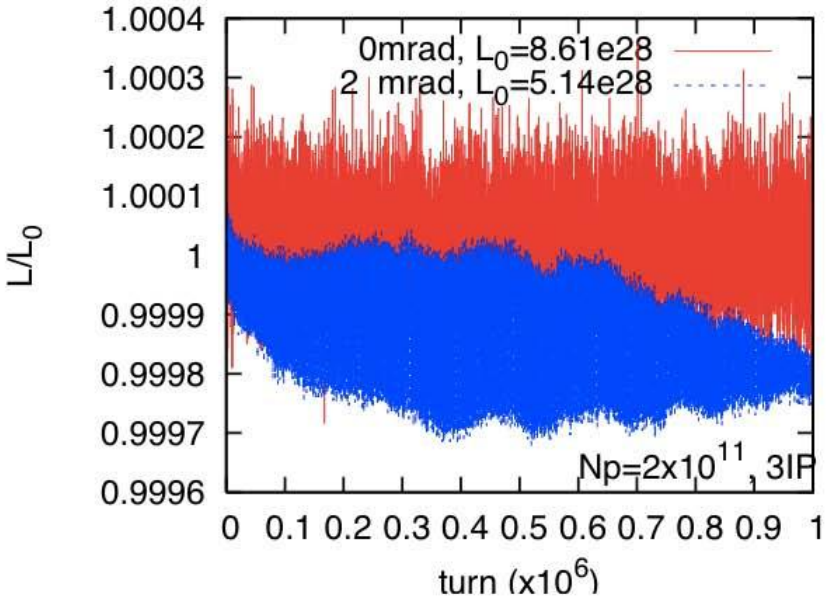
Weak-strong

- 4IP (IP1,2,5,8)



3 IP (IP 1,5,8)



3 or 4 IPs feasible!

difference very clear for 4 IPs

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A difference due to crossing angle is seen with 4IPs, but weak for 3 IPs

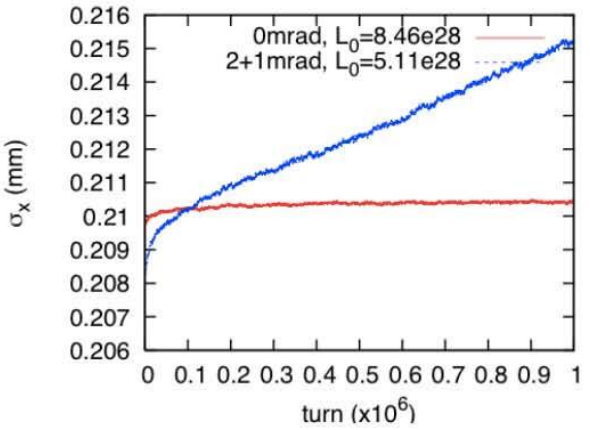
Weak-strong Beamsize

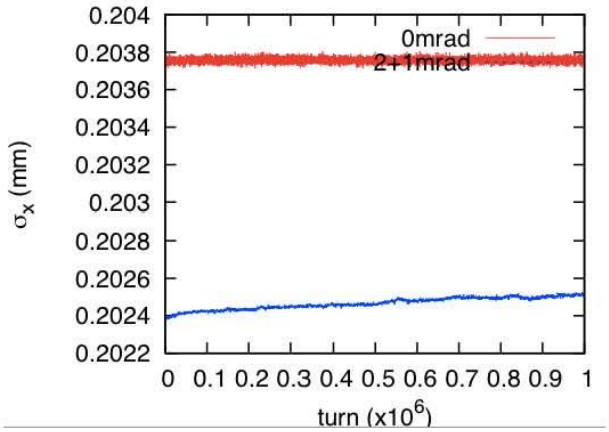
doing the experiment with 4 Ips would be preferred

- 4IP (IP1,2,5,8)

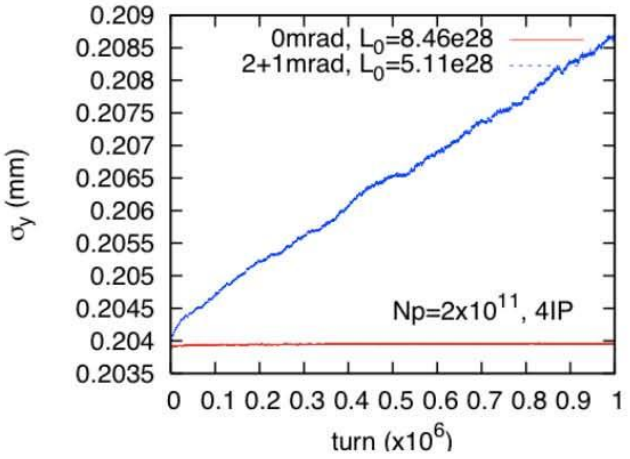
3 IP (IP 1,5,8)

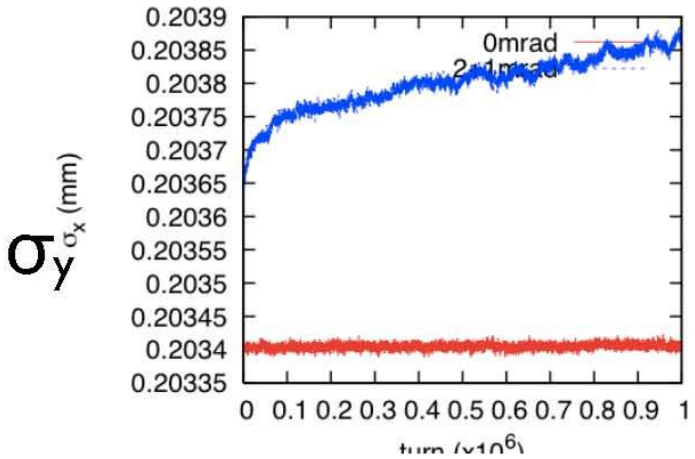
σ_x





σ_y





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