Large Piwinski Angle MD

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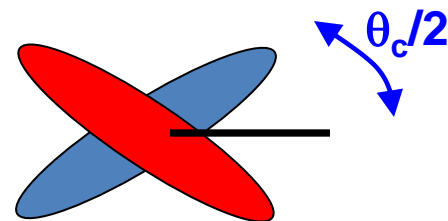
LSWG, 16 August 2011

Piwinski angle

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

"Piwinski angle"

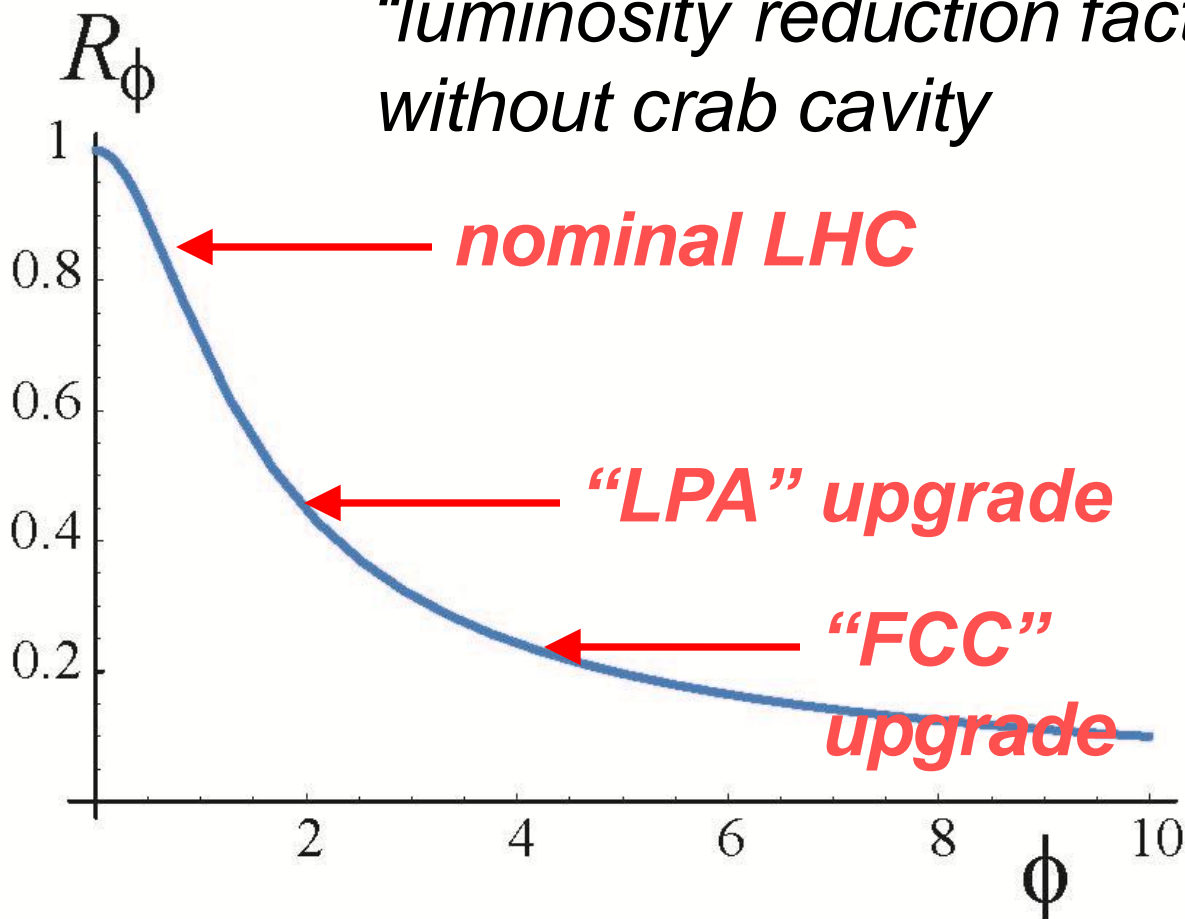*"luminosity reduction factor" without crab cavity*

$\theta_c/2$

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

R_ϕ

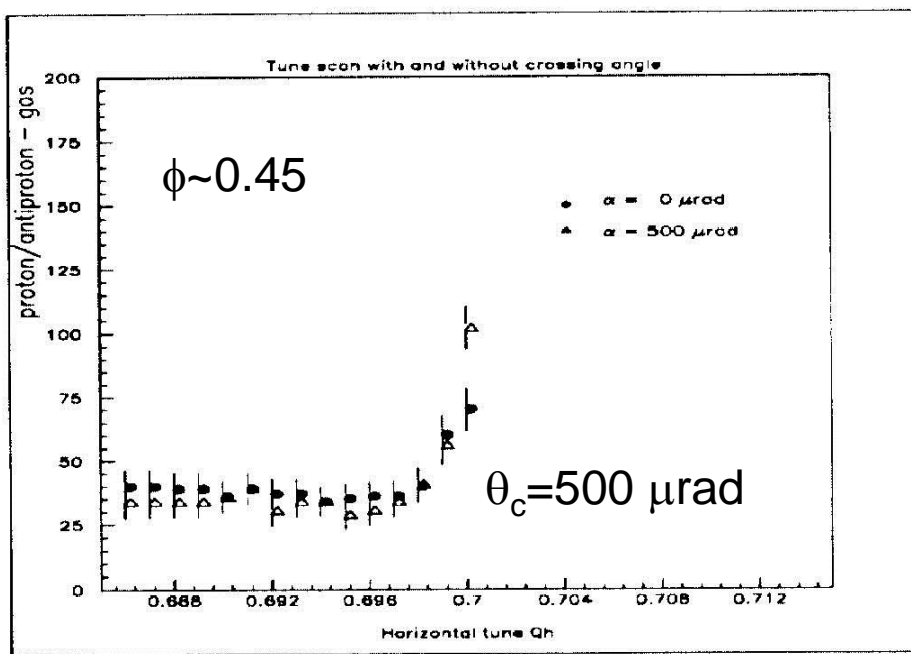nominal LHC

"LPA" upgrade

"FCC" upgrade

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

$\phi \sim 0.45$

$\theta_c = 500 \ \mu rad$

historical experiments
at SPS collider

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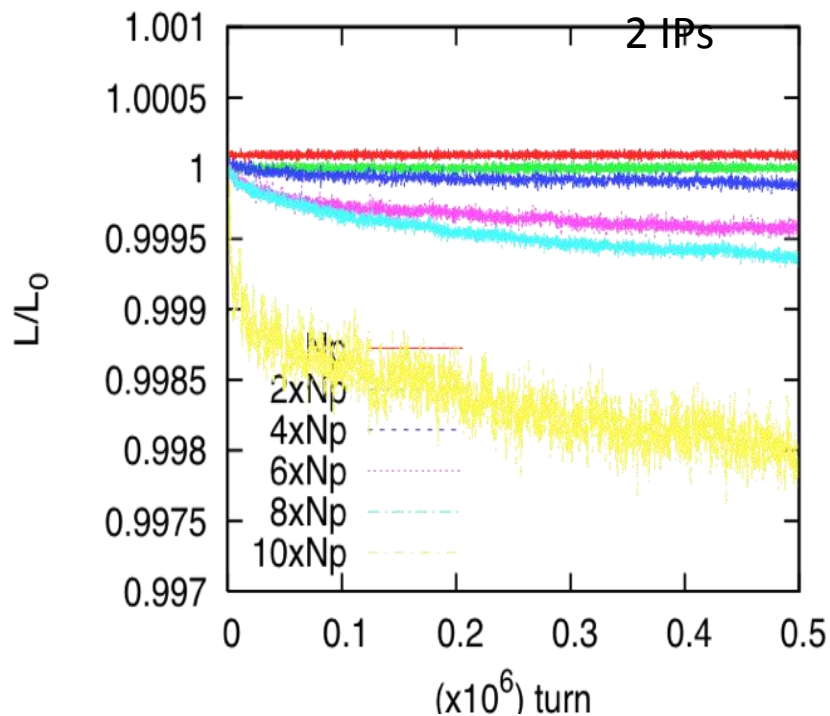Finite Crossing Angle in the SPS",
PAC91 San Francisco

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

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

$\phi > 0.7$

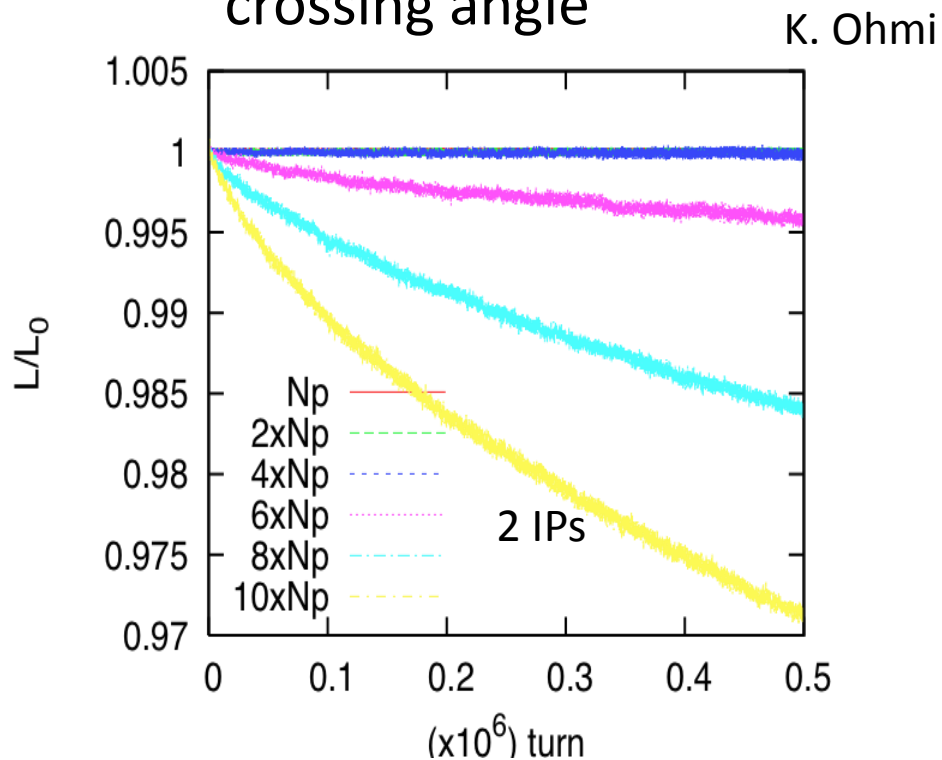$\theta_c = 600 \ \mu rad$
small emittance
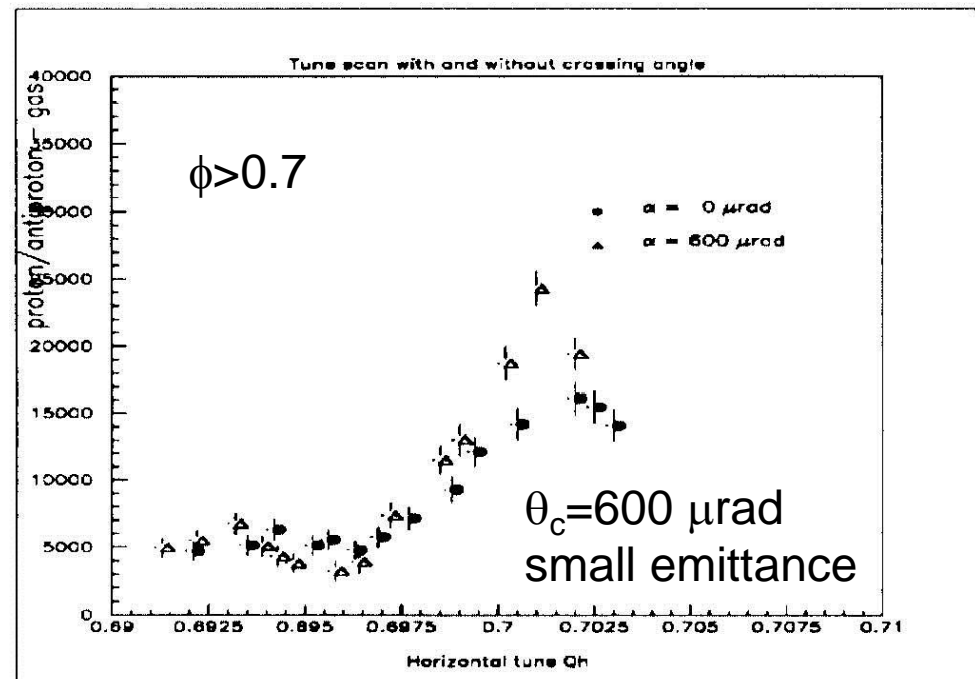
simulations for nominal LHC with higher bunch charge

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 ($\phi \approx 0.65$, $\beta^* = 0.55$m, $\gamma\varepsilon = 3.75$ 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, N_P=3×10^{11}, 2×10^{11}, 1.2×10^{11}.

- σ_z=1.6ns/4=0.12m, σ_δ=3×10^{-4}.

- β_z=σ_z/σ_δ=400m, ν_s=0.0034.

- β^*=10m (3m). $\gamma\varepsilon$=1.5, 2.0×10^{-6}.

- VRF=3 MV (400MHz). η_P=3.18×10^{-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

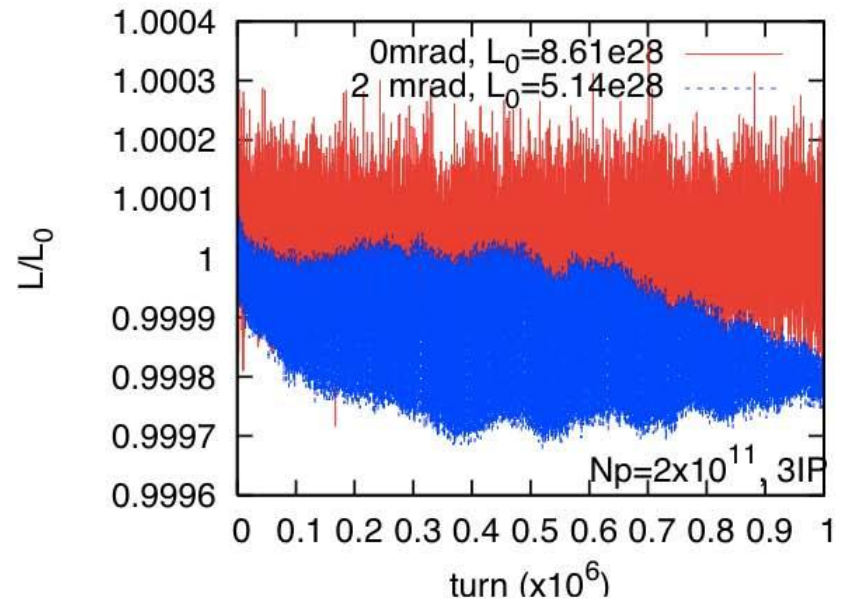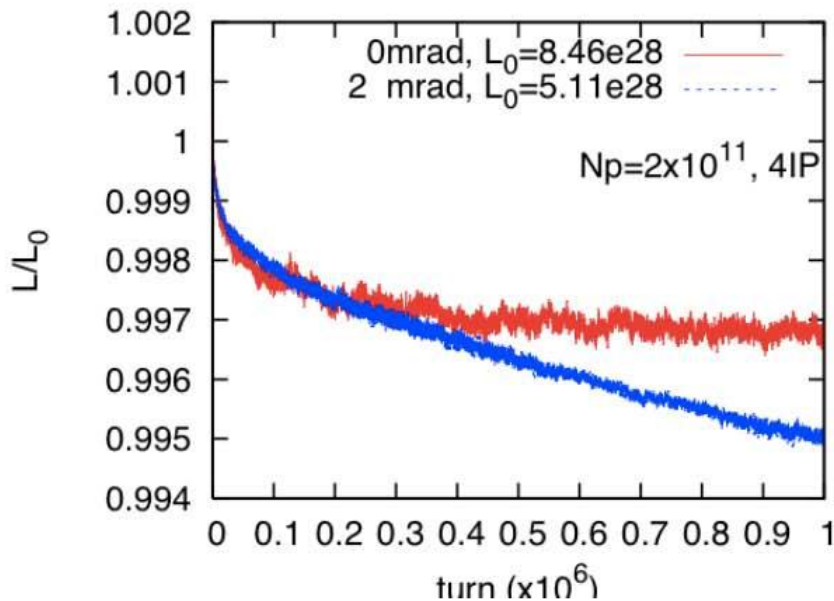10^9 turn/day, $\Delta L/L_0 = 10^{-3}/10^6$ is visible level.
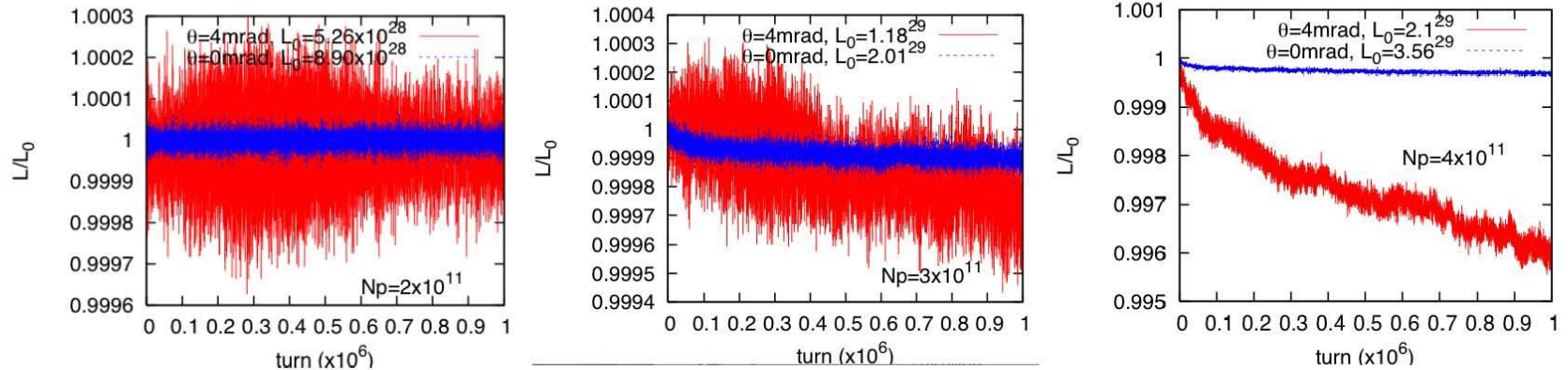
- proton intensity x1, x1.5, x2.

- Np=4x1011 shows clear difference in luminosity degradation.

- Fluctuation is larger in crossing collision.

2 IPs not feasible!

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Weak-strong

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

3 IP (IP 1,5,8)

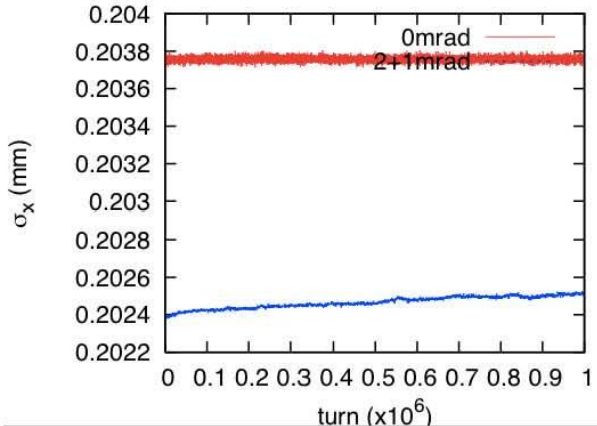*3 or 4 IPs feasible!*
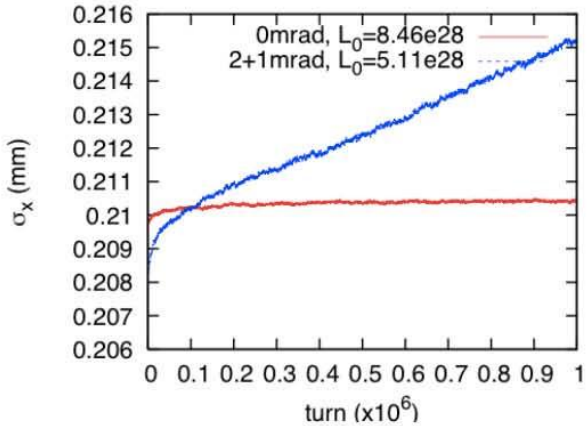*difference very clear for 4 IPs*

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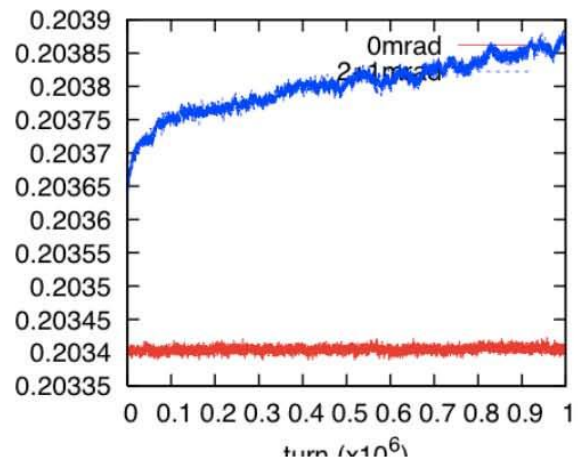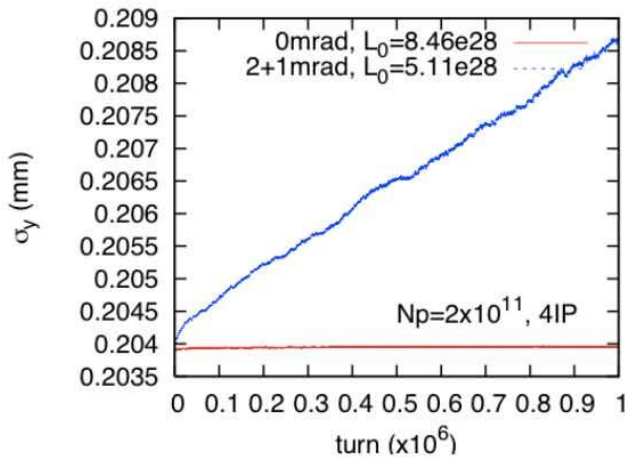
Weak-strong Beamsize

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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