Large Piwinski Angle MD

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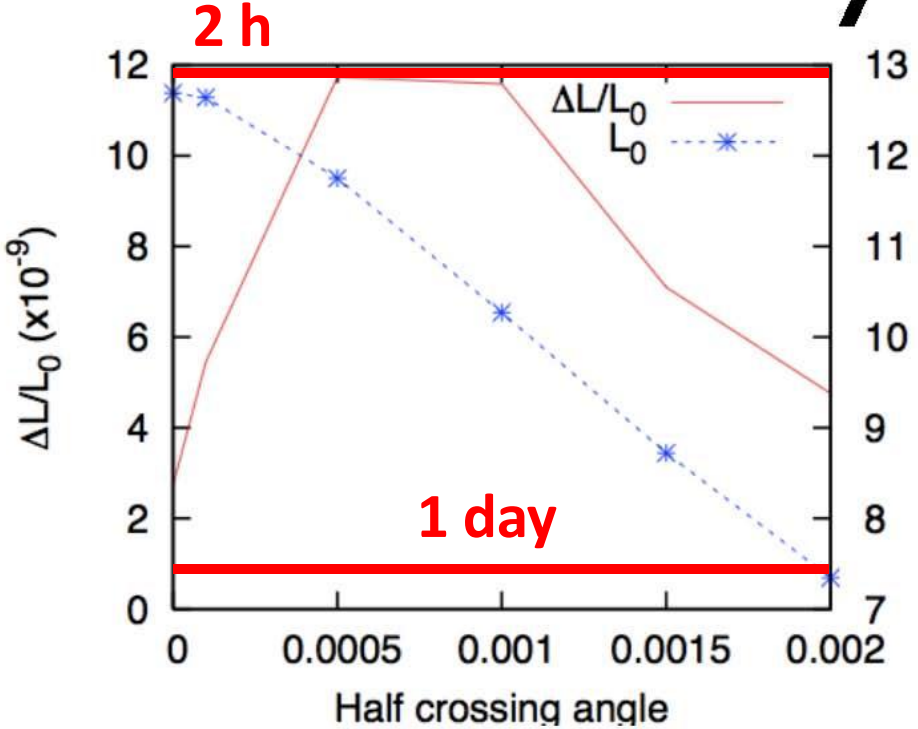
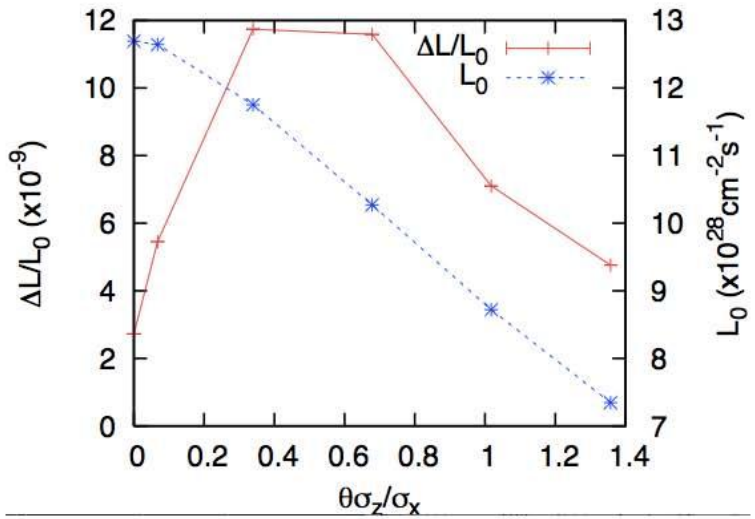
MD plan

- **injection energy, collision tunes**
- **two high-brightness bunches per beam**, 2.5e11, ε~2 μm
- "long" bunches (1.6 ns): blow up in SPS & low voltage in LHC (3.5 MV) [Philippe Baudrenghien]
- **collisions in 3 IPs**
- fill pattern: **one bunch / beam colliding in IPs 1,5 and 8; the other in IP8 only ; tune shift ~0.01 / IP**
- **change IP8 spectrometer in 3 steps from nominal to zero** θ_c=4 → 0 mrad (**TCT adjustment**, & orbit correction at each step?) [nominal, ½, ¼, 0 strength]
- **monitor transient losses going into collision, beam lifetime and luminosity lifetime for large, intermediate, and zero Piwinski angle**

Luminosity degradation





$\Delta L/L_0=10^{-9}$: 1 day

- $L=L_0-\Delta L\ t/T_0$ (L_0 is different from previous page)
- Fit 3×10^5-10^6 turns
- We can see the difference for crossing angle.

MD simulation by K. Ohmi

MD plan – cont'd

- in order to save time the **TCTs might not be readjusted, in which case they should be at intermediate settings** and the pertinent **BIS interlock** be masked; **masking is only possible when the total intensity is below 5e11 at 450 GeV**
- new **IR reference for orbit feedback** needed after spectrometer change if the feedback is active and/or **orbit correction if the internal crossing bump is insufficiently closed** when moving the spectrometer and the compensator in IR8; **transverse damper** probably not needed
- collision tune, e.g. **new ref. values sent to QFB**
- **diagnostics needed:** orbit, bunch intensity, bunch lifetime, bunch length, emittance, tune signal, Schottky spectra

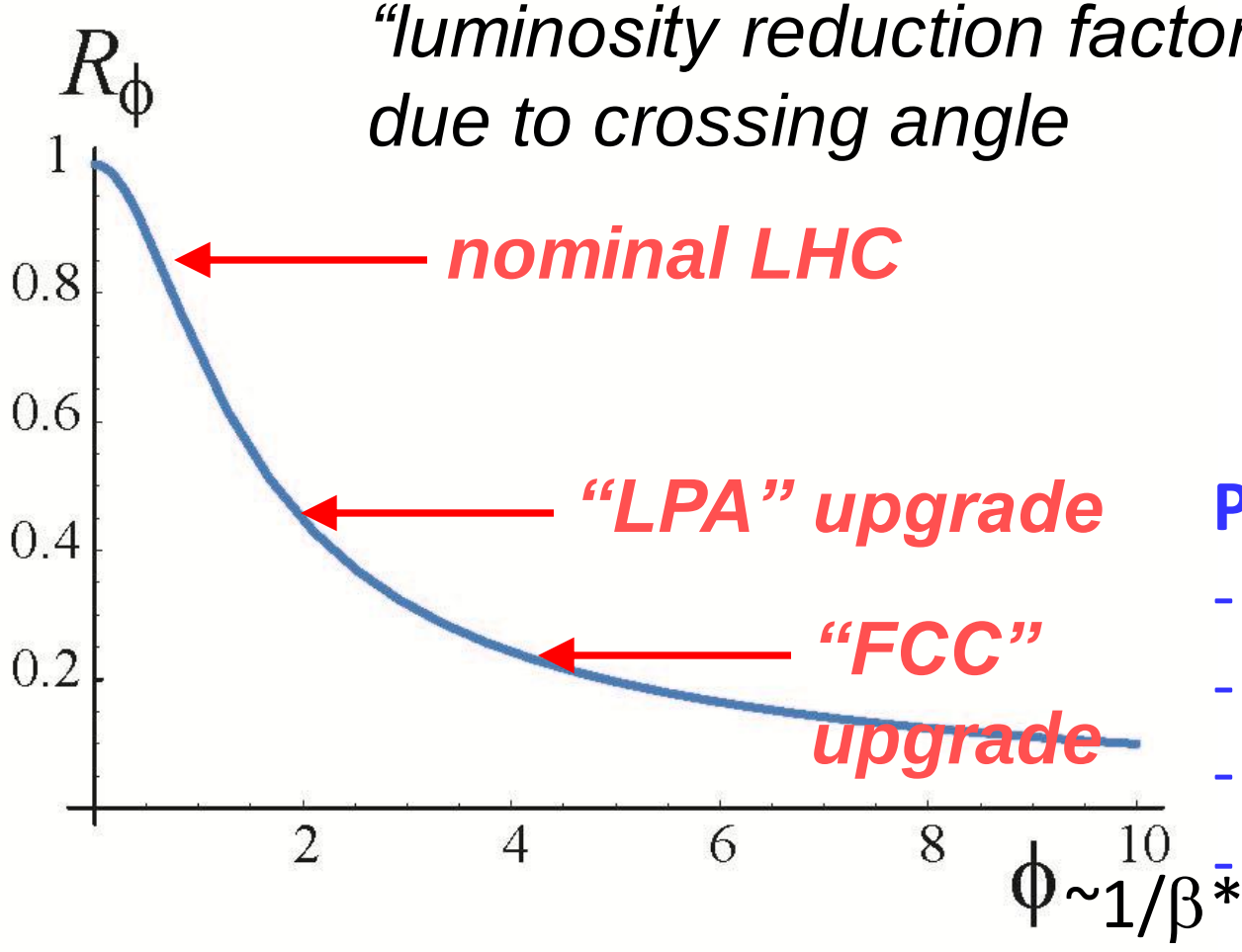
appendix

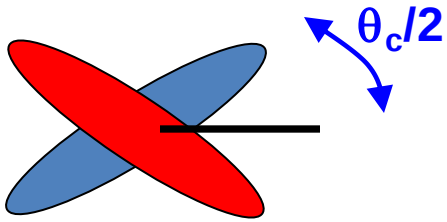
Piwinski angle

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

"Piwinski angle"

"luminosity reduction factor" due to crossing angle





effective beam size:

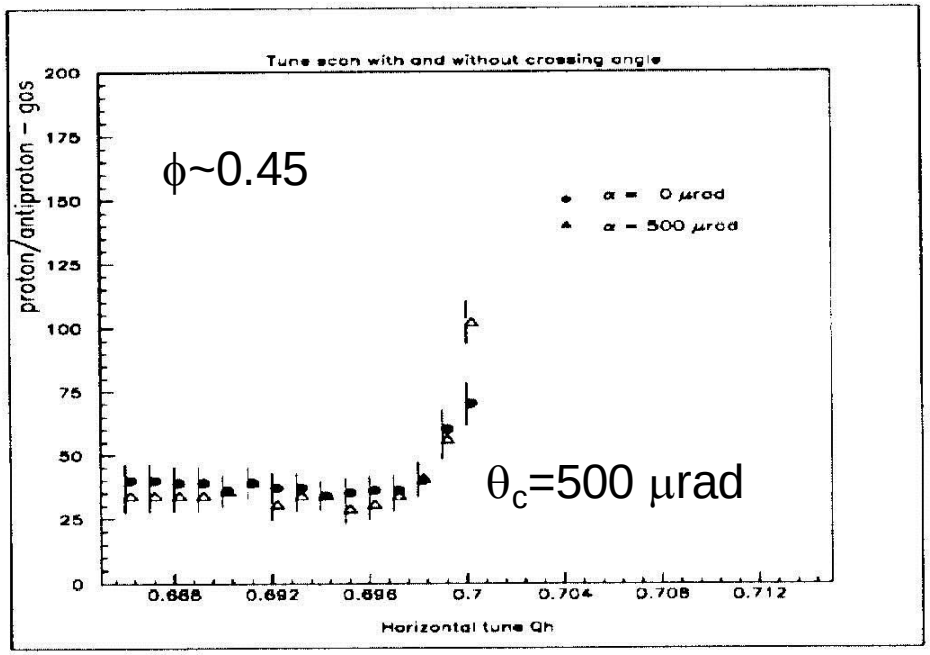
$\sigma^*_{x,eff} \approx \sigma_x^* / R_\phi$

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

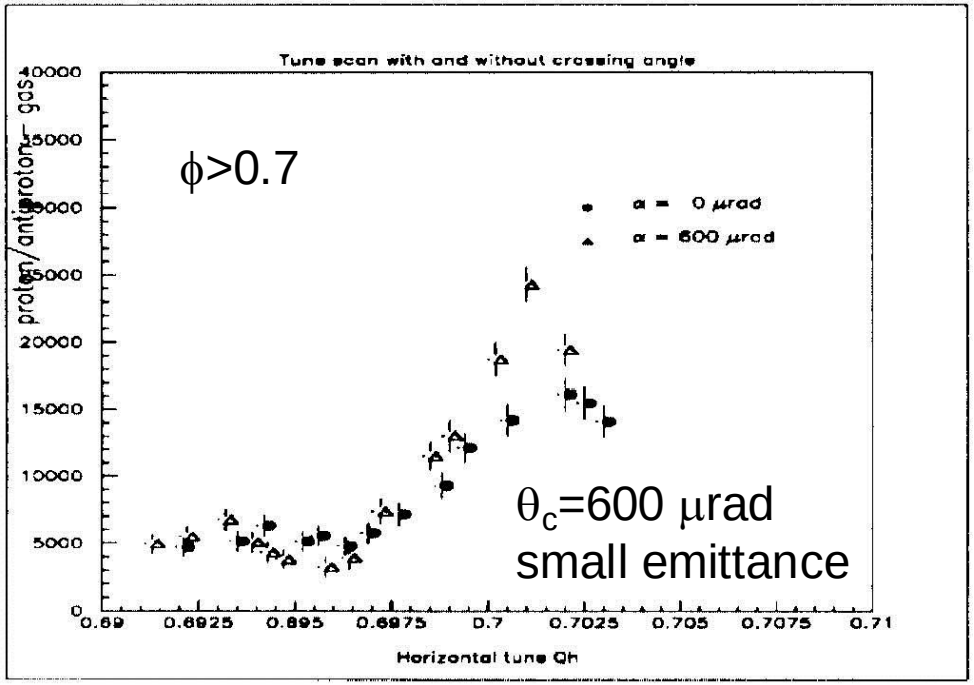


historical experiments at SPS collider

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

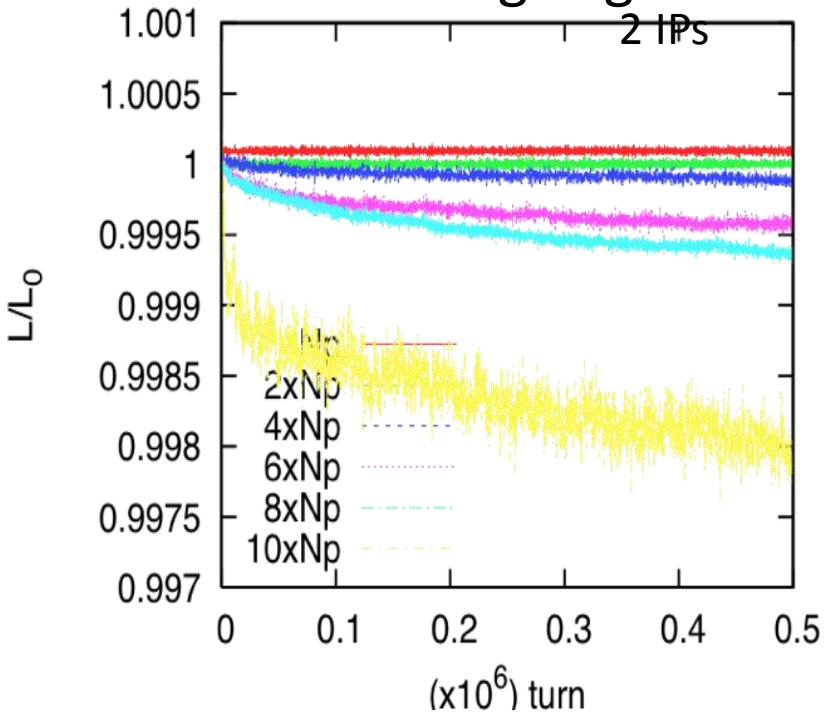
SPS tests up to ϕ>0.7 showed some additional beam-beam effect

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



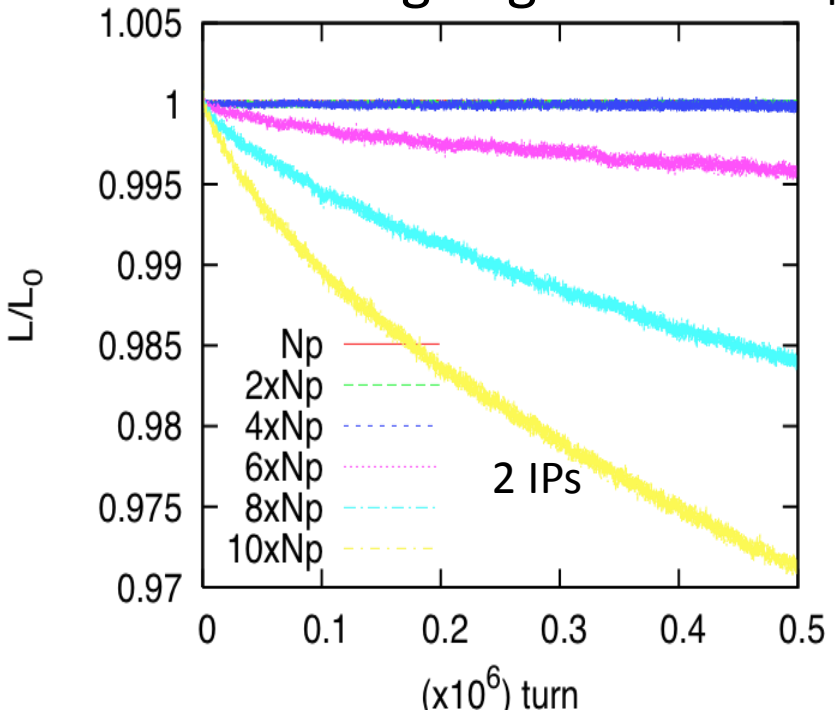
simulations for nominal LHC with higher bunch charge

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)

further pushing the Piwinski angle

a squeeze of IR8 down to β^*=5 m at zero external crossing angle could eventually be done in an eventual second LPA MD in order to further boost the Piwinski angle to the highest values considered for the HL-LHC

with β^*=10 m and 2 mrad half crossing angle in IP8 the Piwinski angle reaches 1.5 (twice as high as previous studies), with 5 m β^* the Piwinski angle will exceed 2