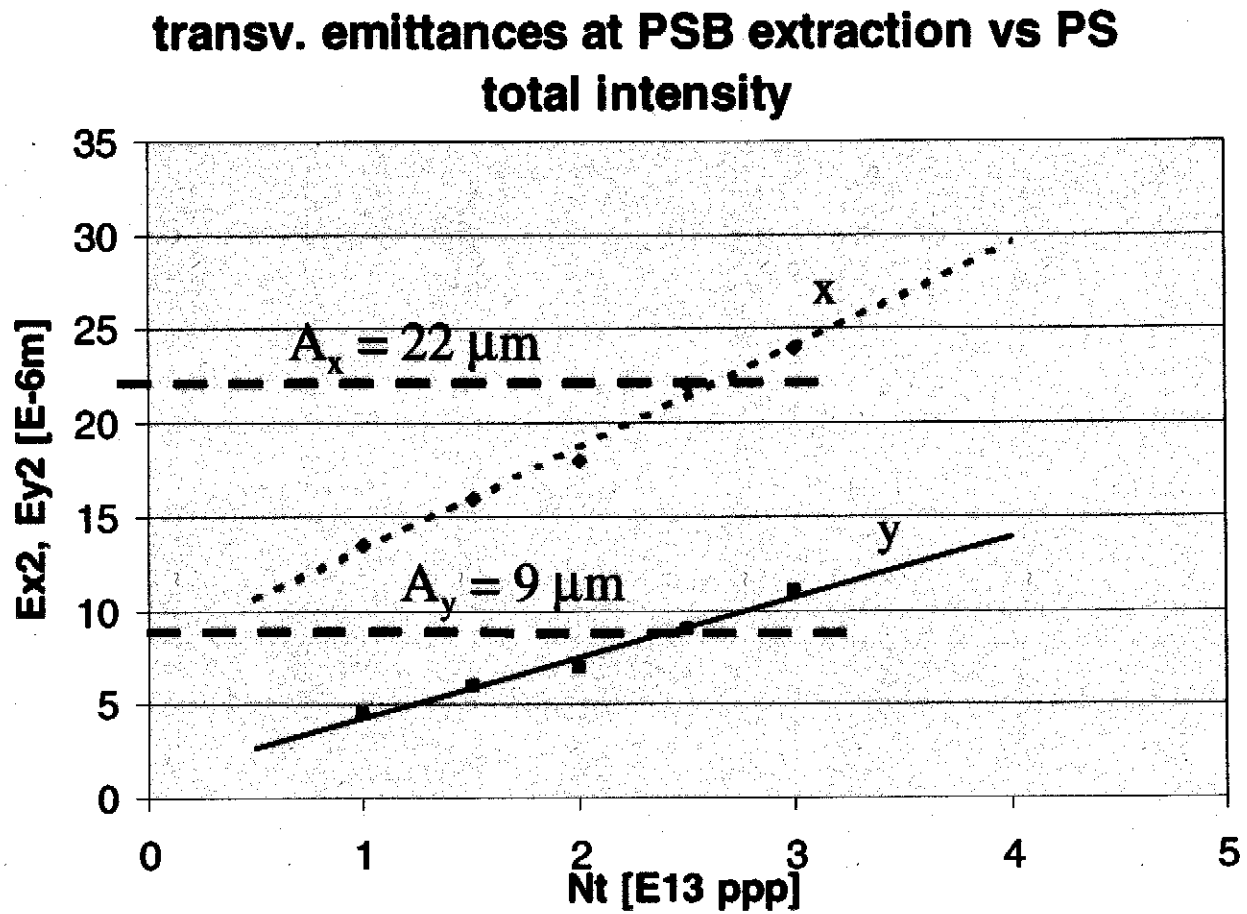
High density and high intensity beams at CERN-PS: present studies, achievements and future goals

R.Cappi / CERN-PS/ FNAL 2002

- High **density** beams:
  - LHC nominal : $k_b = 72$; $N_b = 1\ 10^{11}$ p/b; $\varepsilon^*_{rms,\,x/y} = 3/3\ \mu m$
  - LHC ultimate : $k_b = 72$; $N_b = 1.7\ 10^{11}$ p/b; $\varepsilon^*_{rms,\,x/y} = 3/3\ \mu m$
- High **intensity** beams:
  - Single bunch (nTOF): $k_b=1$; $N_b= 0.7\ 10^{13}$ p/b; $\varepsilon^*_{rms,\,x/y} = 5/3\ \mu m$
  - <u>Multibunch (CNGS): $k_b=16$; $N_t= 3\ 10^{13}$ p/p; $\varepsilon^*_{rms,\,x/y} = 5/3\ \mu m$</u>

Why a double batch injection?

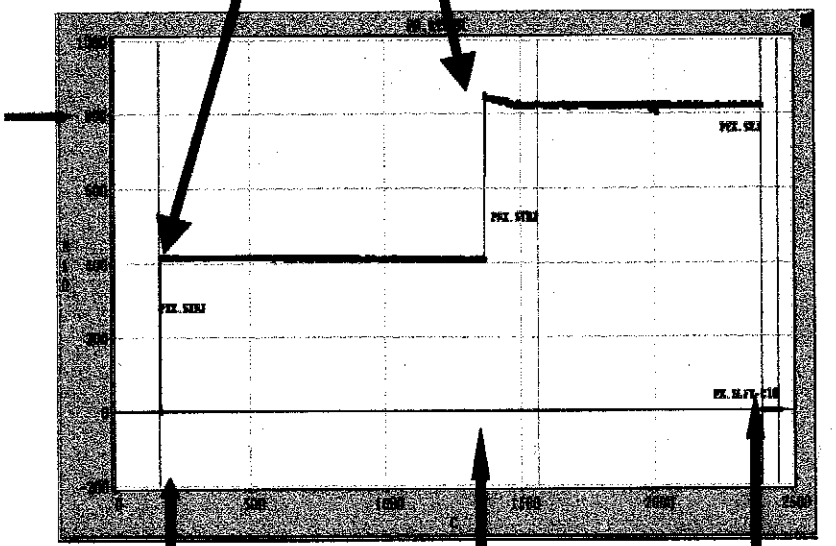


NB: A double batch injection is necessary if $N_t > 3\ 10^{13}$ ppp

High density beam: LHC nominal

Double batch injection to gain x2 in brilliance

PS intensity vs t (2.5s total time)

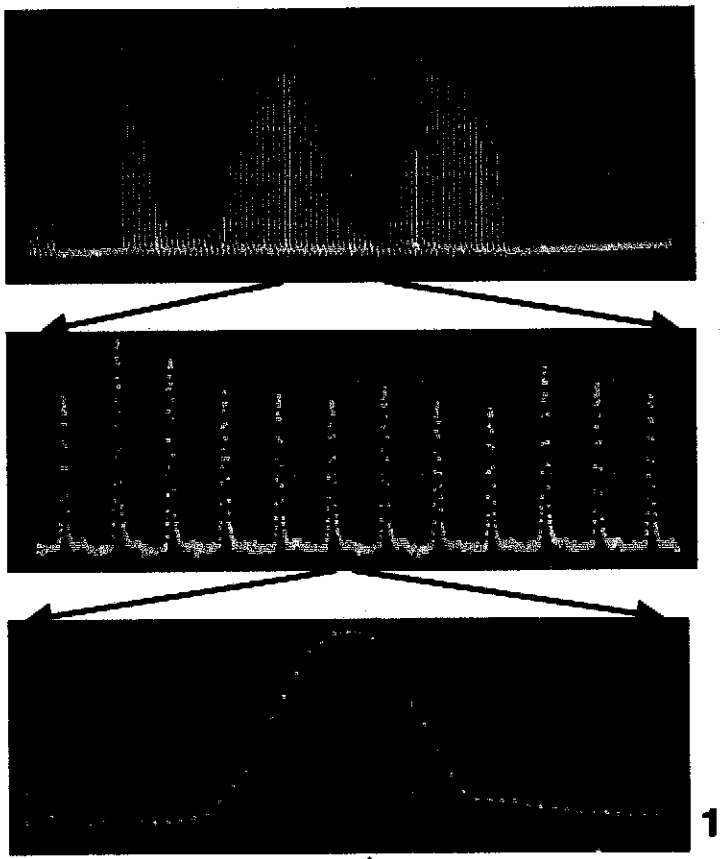


1st batch injection

2nd batch injection

Extraction @ 26GeV/c

Last turn (72 bunches spaced by 25ns)



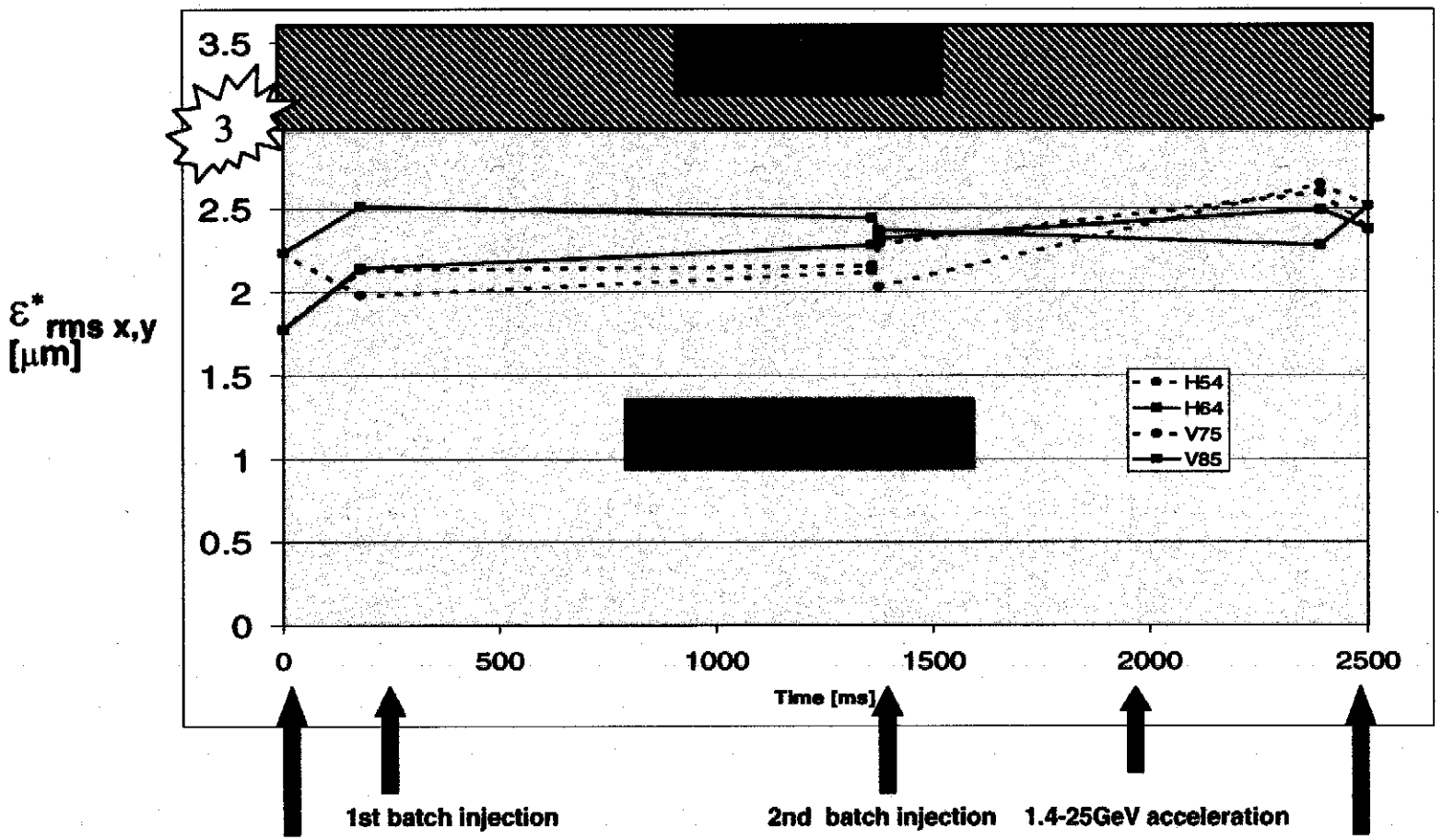
1 ns/d

Bunch before extraction

$N_b = 1.1\ 10^{11}$p

$4\sigma_t < 4$ ns

Transverse emittance conservation



PSB output

(SEM grids in meas. line)

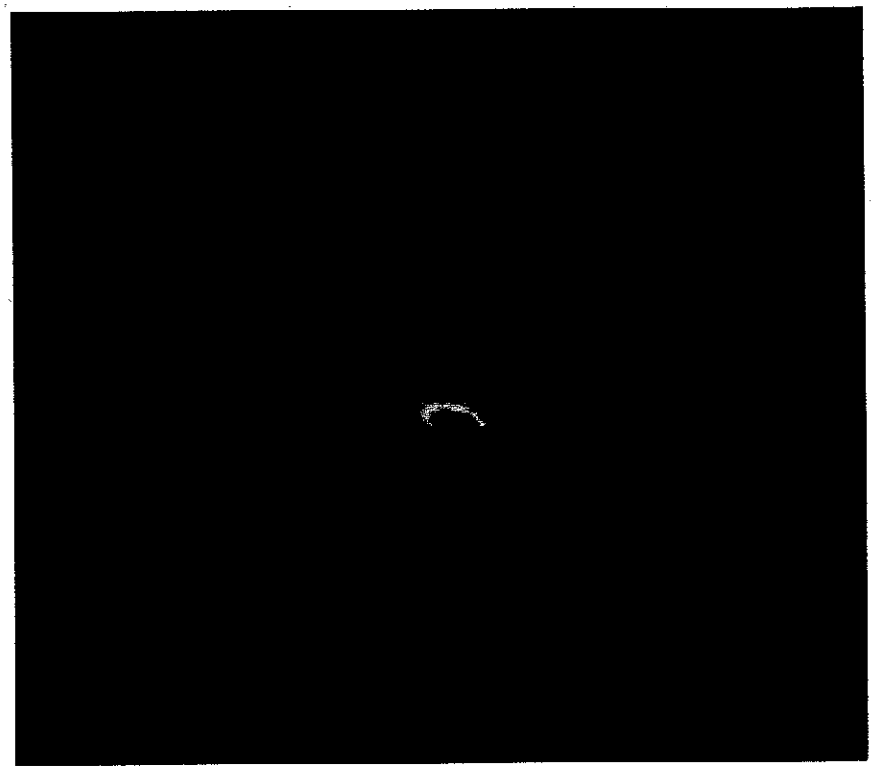
PS output

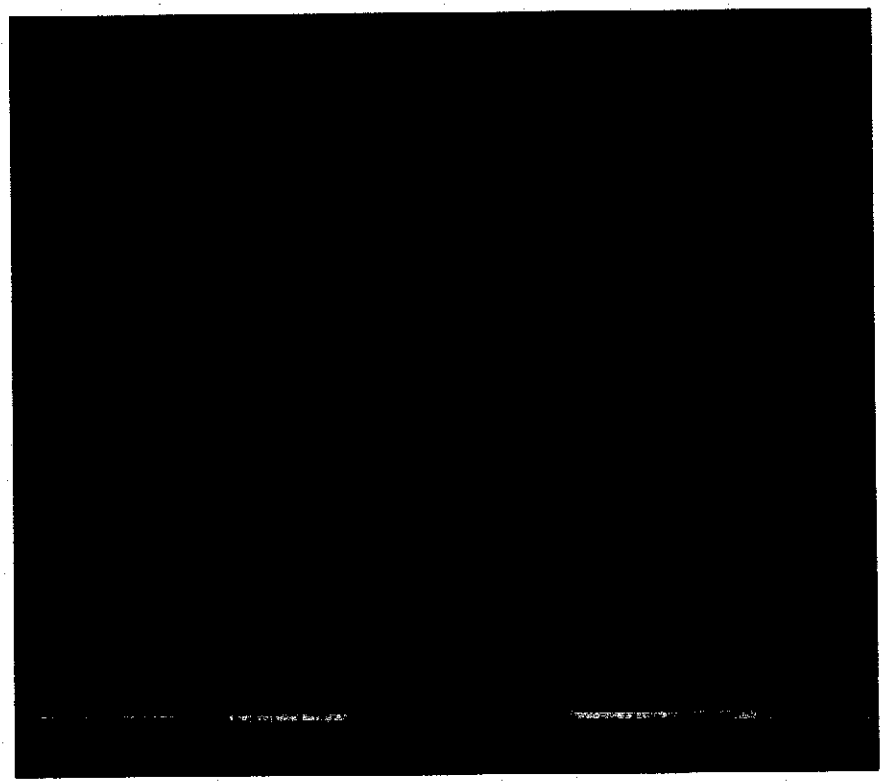
(SEM grids in TT2 line)

High intensity, single bunch: nTOF

N_b=0.7 E13 p/b, rms bunch length = 6ns

Final bunch compression

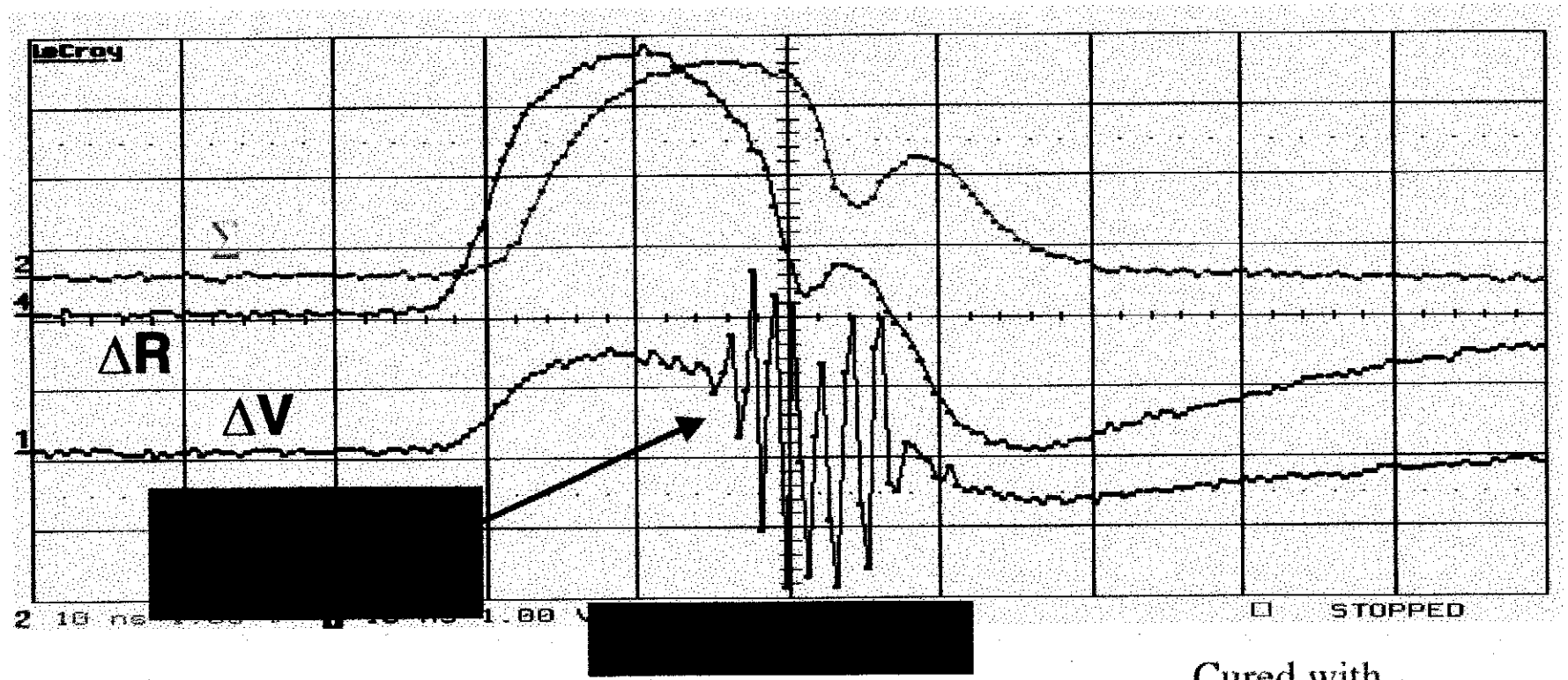




Time scale: 20ns/div

Courtesy G.Metral

nTOF: **Vertical Mode-Coupling instability** due to a BB impedance when $N_b > 4\ 10^{12}$ p/b and $\varepsilon_l < 1.2$eVs



Stable if:

$$\varepsilon_l \geq N_b \times \frac{e\beta}{2|\eta|} \times \frac{\beta_y \left| Z_l^{BB} / p \right|}{b} \times \left| 1 + \frac{f_{\xi_y}}{f_r} \right|^{-1} \Rightarrow \varepsilon_l \geq \sim 2 \text{ eVs}$$

Cured with ctrl. long. b.u.

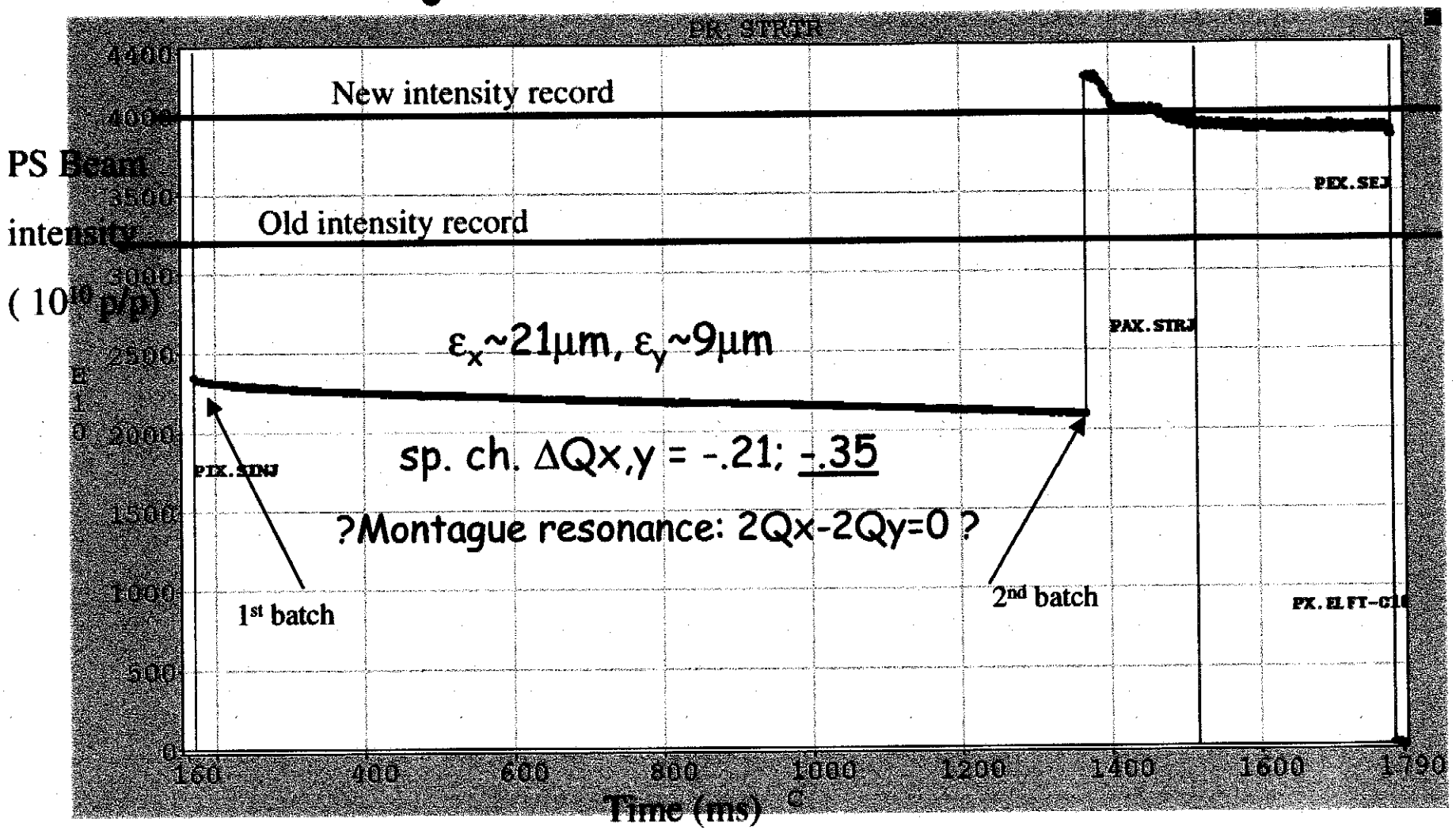
High intensity, multibunch: CNGS

- 'CNGS nominal' in CPS: 3.3 10^{13} ppp

- 'CNGS improved' in CPS: 4.8 10^{13} ppp (goal)
  =max. PS intensity limited by <u>acceptance</u> AND <u>$\Delta Q<0.3$</u>
  - Doubling PSB rep. rate (1/1.2s => 1/0.6s)
  - ➡ Double batch injection
  - ➡ Bunch flattening (space charge)
  - ➡ New 5t Continuous Transfer

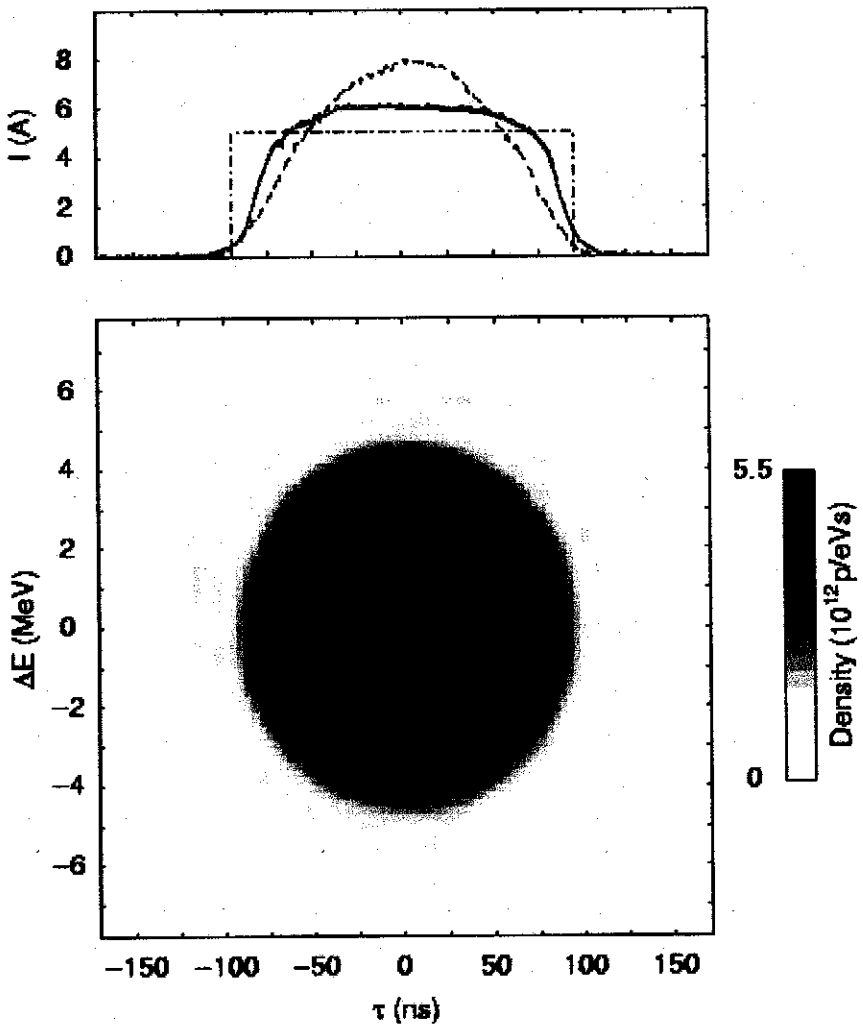
...expected gain in pot/s ~ 1.6

Recent results of high intensity double batch injection studies for CNGS



Courtesy E. Metral

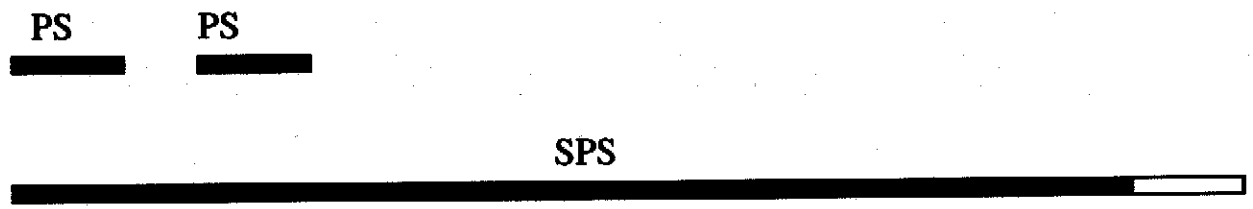
Reducing space charge effects with bunch flattening :



5turn Continuous Transfer

It is the way the PS uses to fill the SPS (at 14 GeV/c)

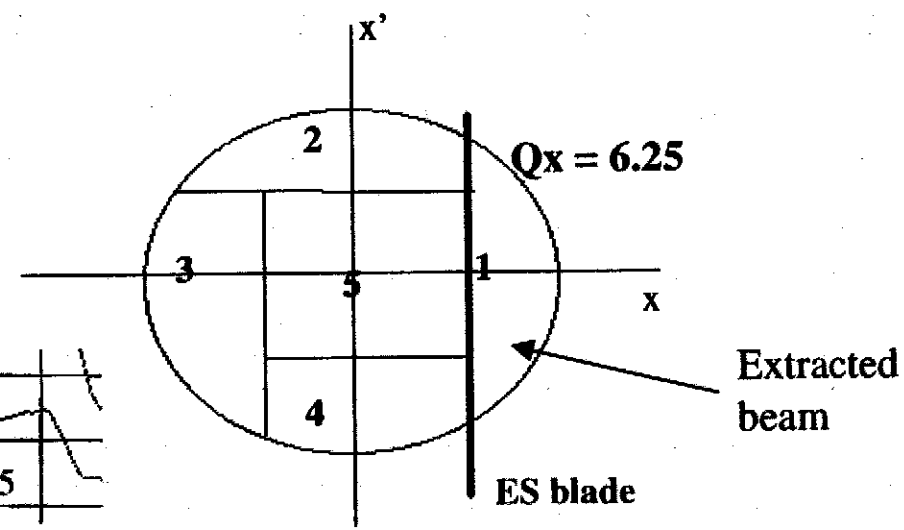
$C_{SPS} = 11 \times C_{PS}$



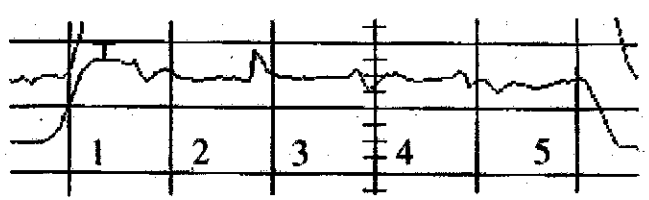
Present system:

+ it works

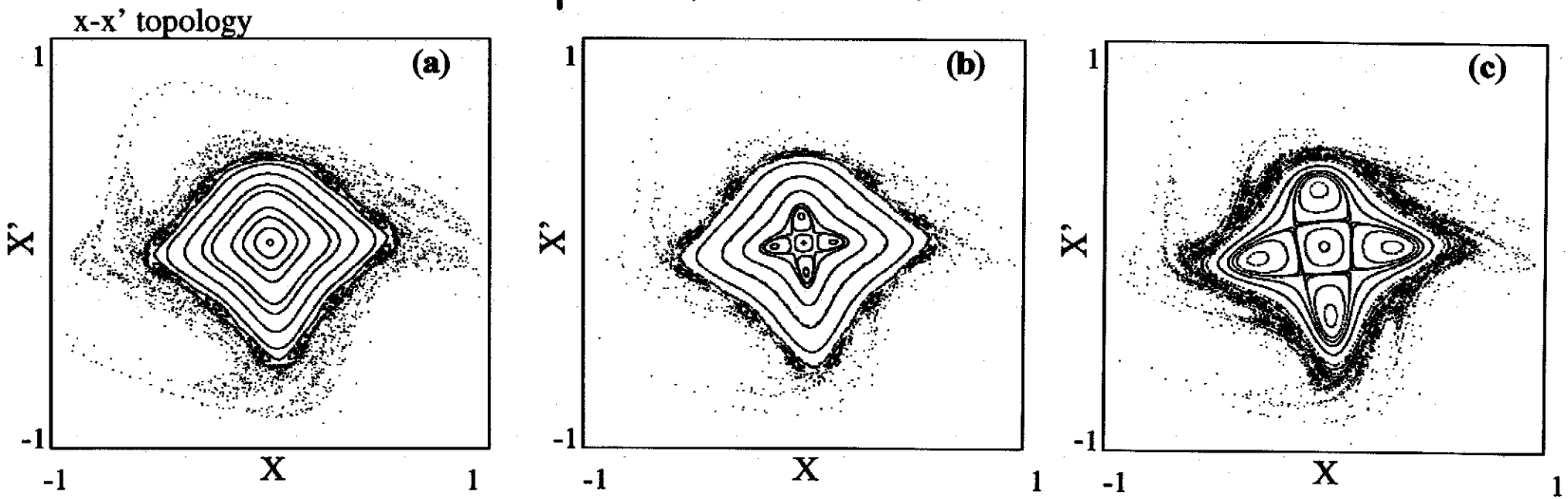
- it is **lossy** (~20%)



Transfo in the transfer line

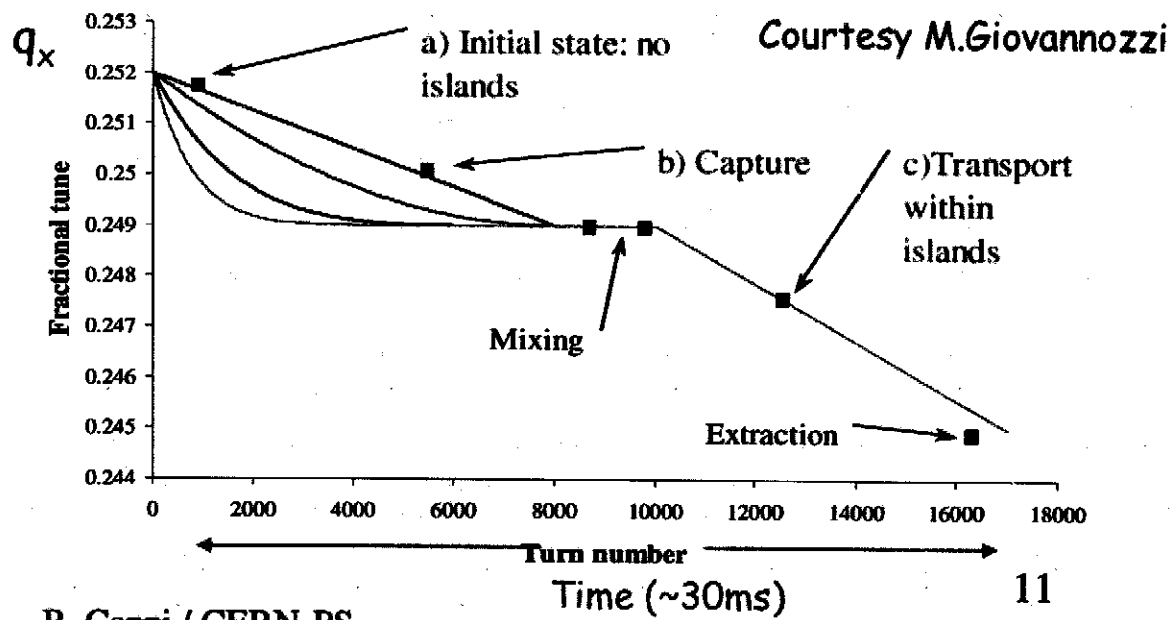


Proposal for a NEW 5tCT

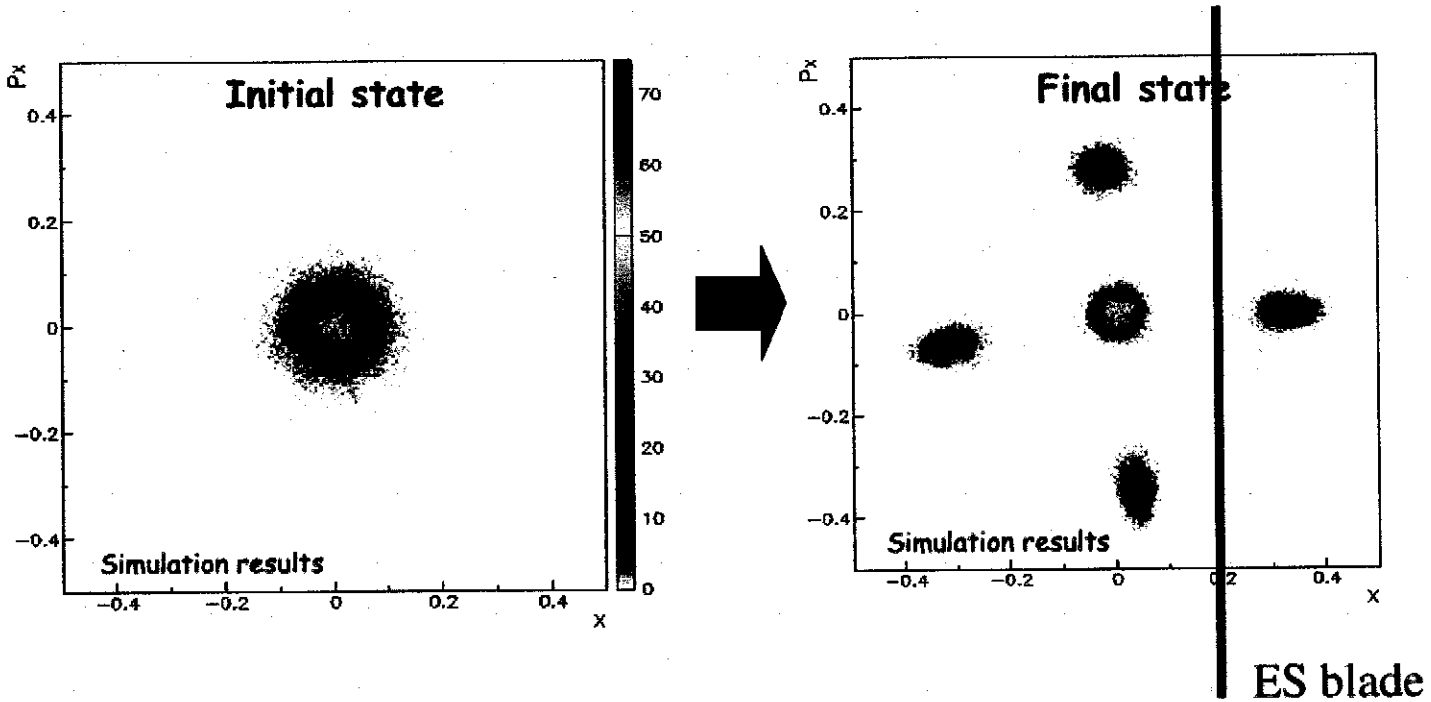


Courtesy M.Giovannozzi

Playing with quads, sextupoles and octupoles, the beam is adiabatically captured into 4 islands (+1) and then extracted as before



n5tCT advantages:
~no losses,
better matching,
higher intensity

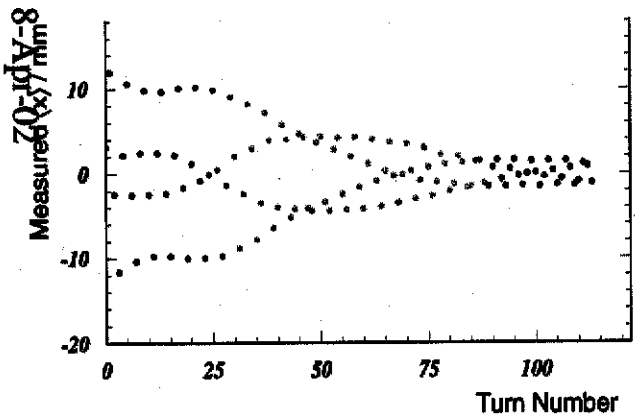


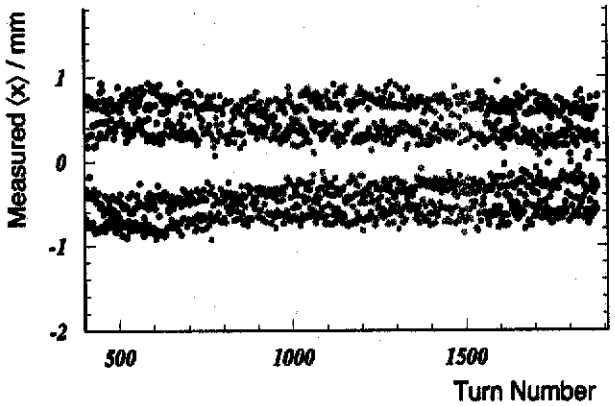
Courtesy M.Giovannozzi

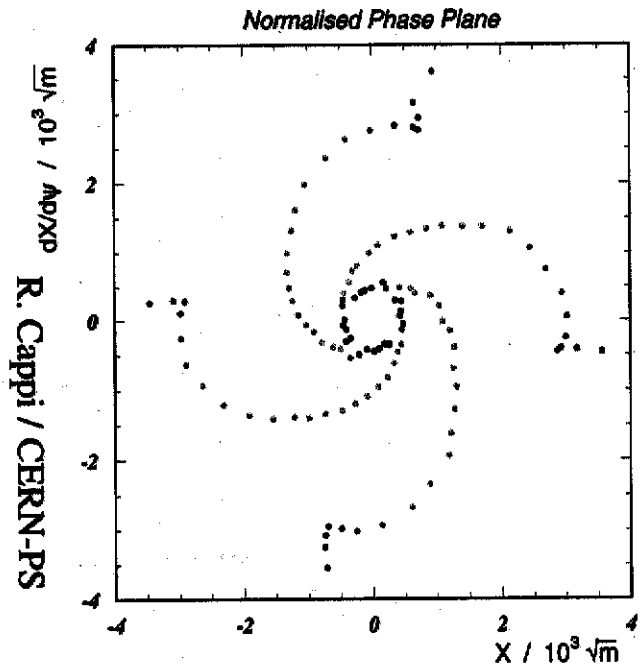
Q: How do we know that we have 'produced' four islands with the right size and right phase ?

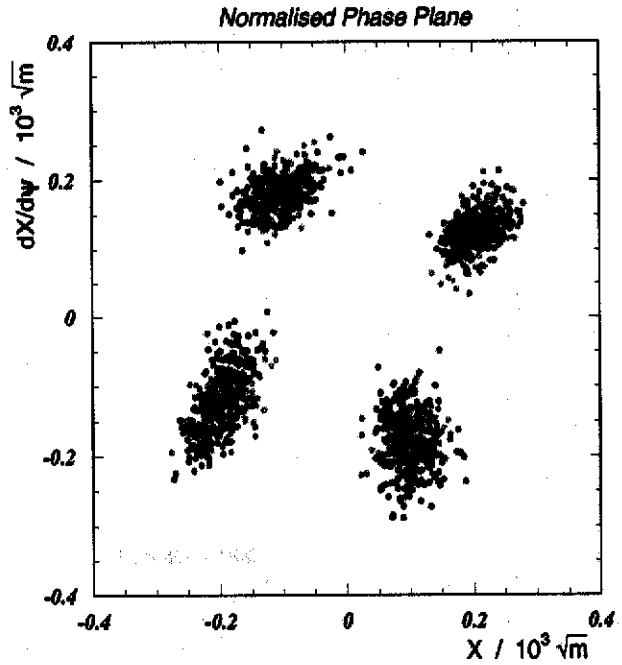
A: Probing the x-x' phase space by kicking a beam and sampling t. by t. its position on 2 bpm's at $\lambda/4$ => x-x'

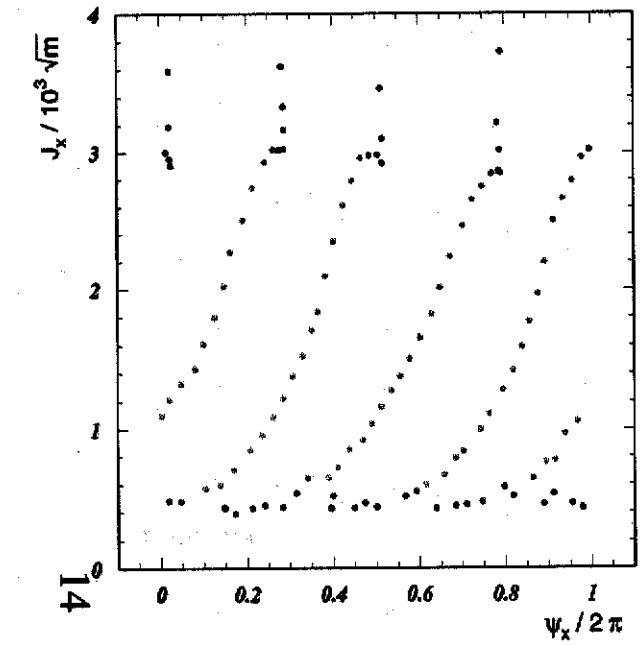
n5tCT: x-x' measurement results

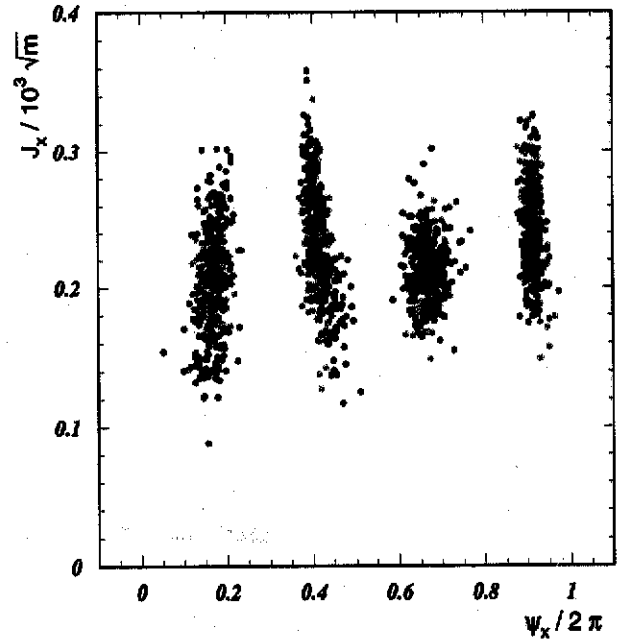






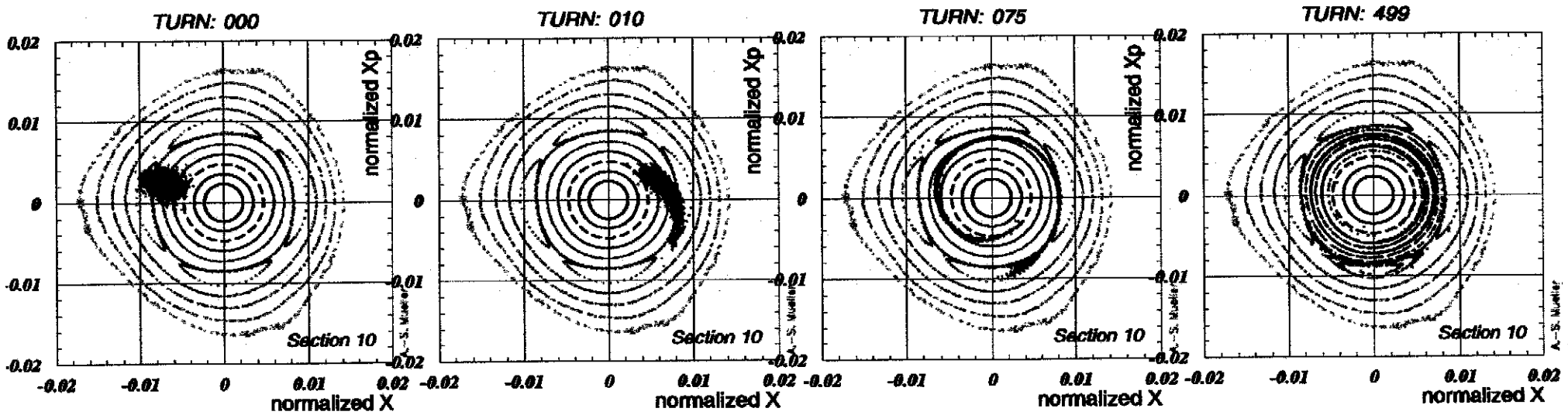


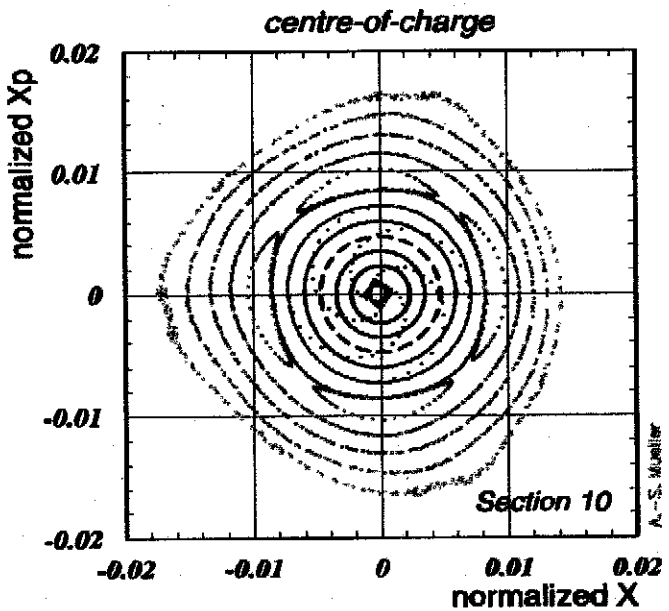


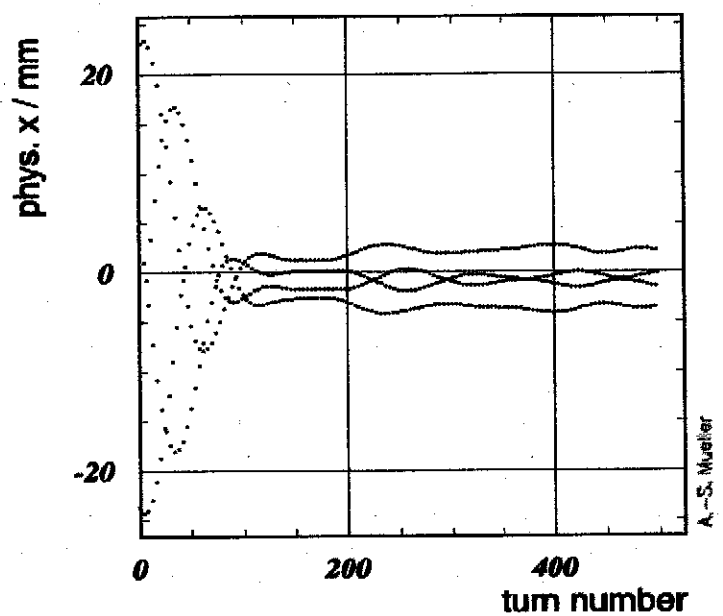


Courtesy M.E.Angoletta, A-S.Muller, M.Martini,...

MAD simulations

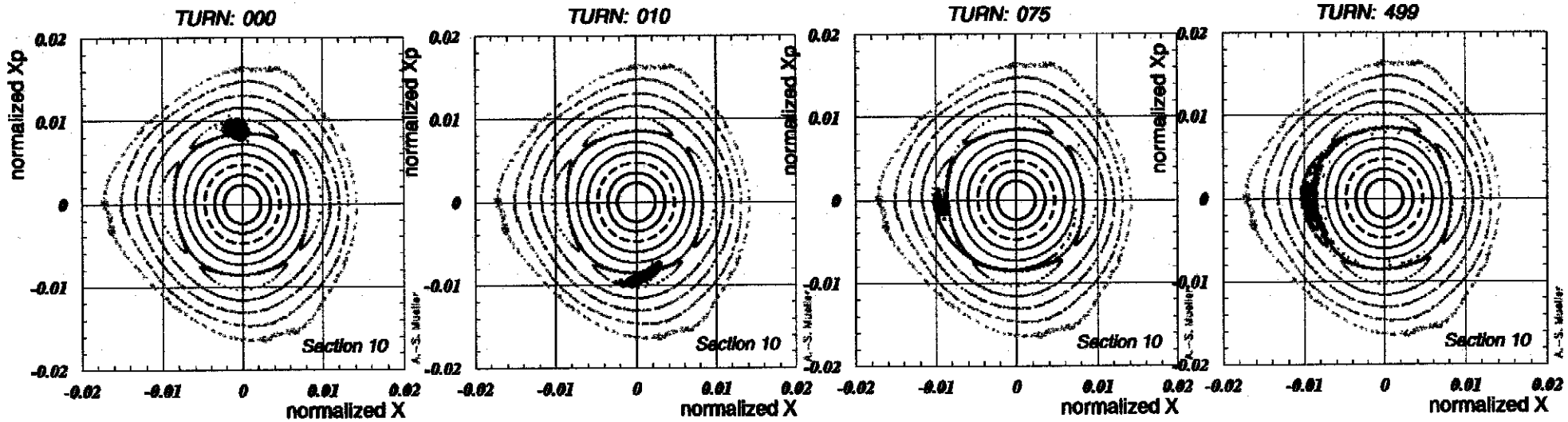


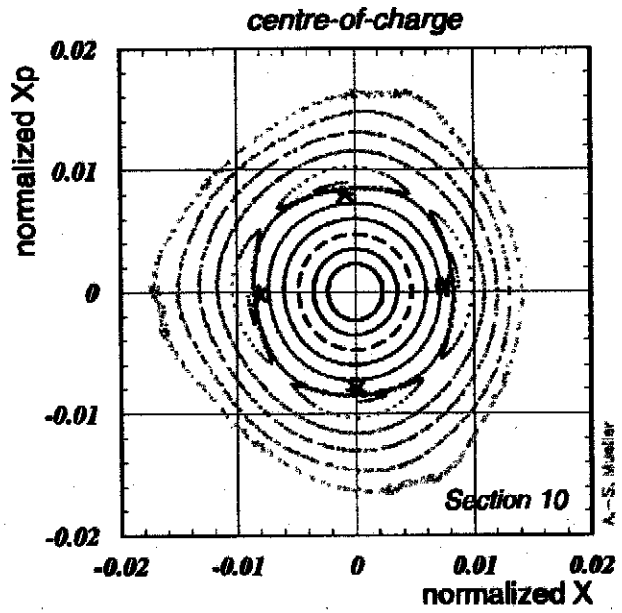


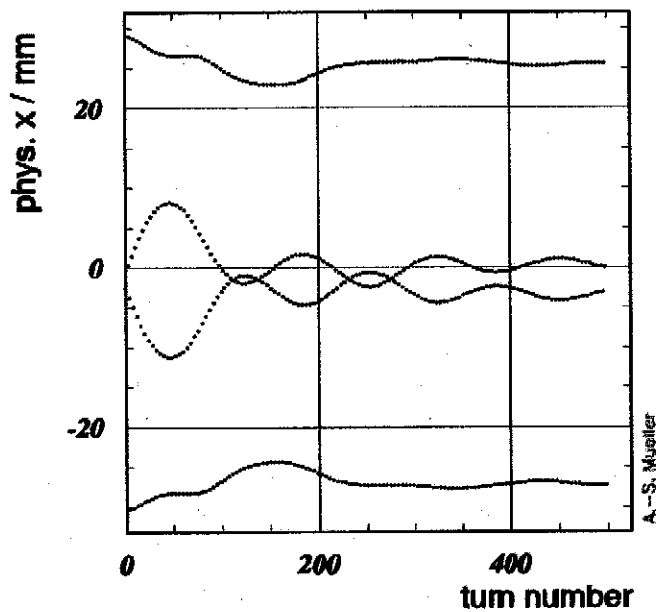


Courtesy A-S.Muller

MAD simulations (suite)







Courtesy A-S.Muller

Conclusion

- High density (LHC):
  - nominal: *done*
  - ultimate: *almost done*
  - Next: initial beam, 75ns bunch sp., MD beams, etc.

- High intensity (CNGS):
  - sp. ch. at low energy : *hollow bunches to be tested , Montague resonance, ...*
  - double batch inj.: *improve machine acceptance*
  - new 5t CT: *sext. and oct. placed; 1st tests this year*
  - long. aspects,...

For all: 120MeV H- linac, 2.2 GeV SPL ?