AD Status and Challenges

- An *economic* antiproton source
- Basic AD cycle
- Stochastic and electron cooling
- Operating modes for commissioning
- Challenging and long commissioning! Why?
- Present performance: Intensities, emittances etc.
- Outstanding issues and improvements for 2001
- Conclusion

A personal view by Flemming Pedersen….

Abstract

The present status and performance of the AD is presented. The commissioning of the machine was a long and challenging exercise for the people concerned. The reasons for this somewhat long commissioning are presented:

i) inadequate quality control during installation,

ii) intensities are one to two orders of magnitude lower than any other synchrotron in the PS complex

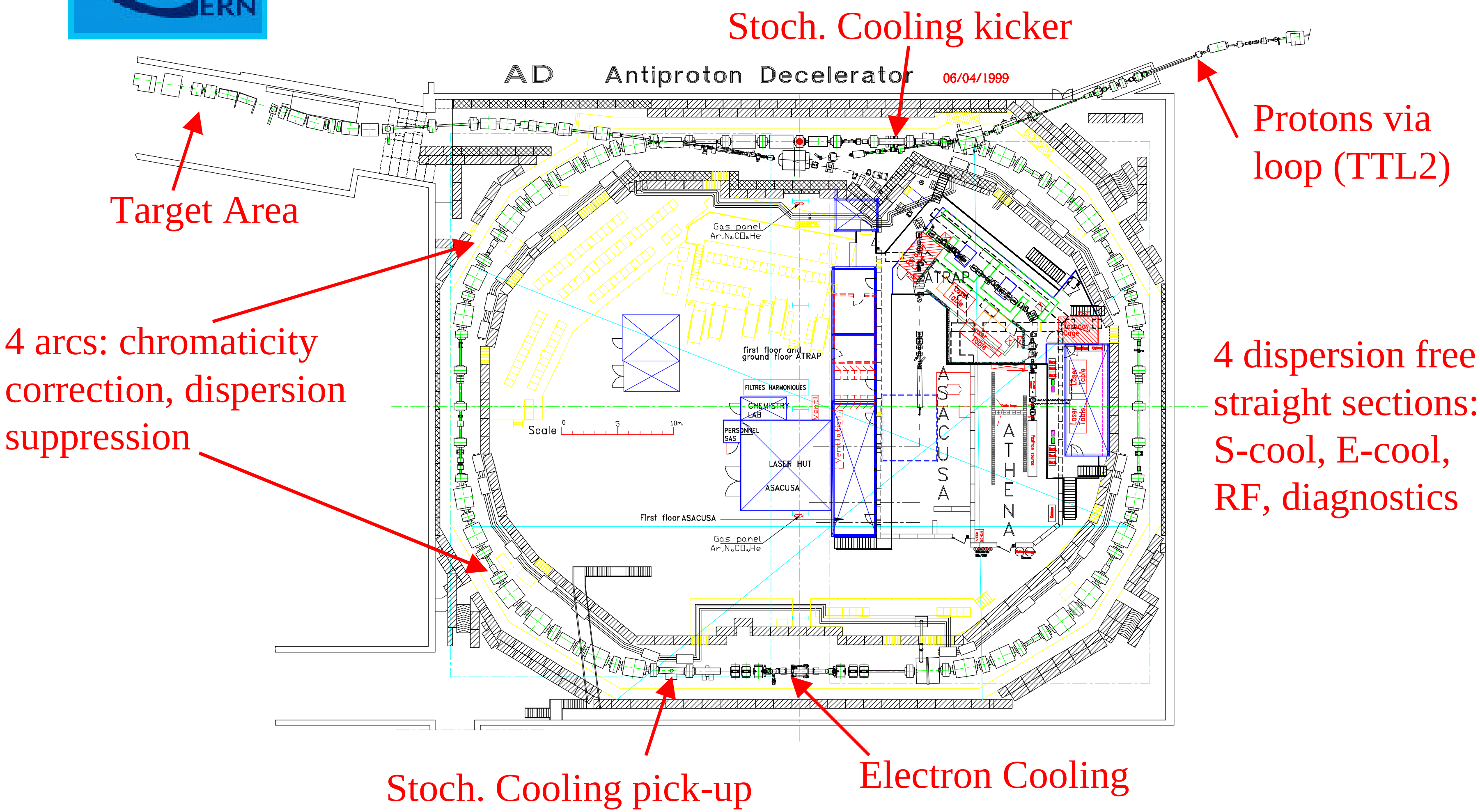
iii) the optics is fairly complex while existing magnets were used.

The few remaining outstanding issues and desired improvements are outlined.

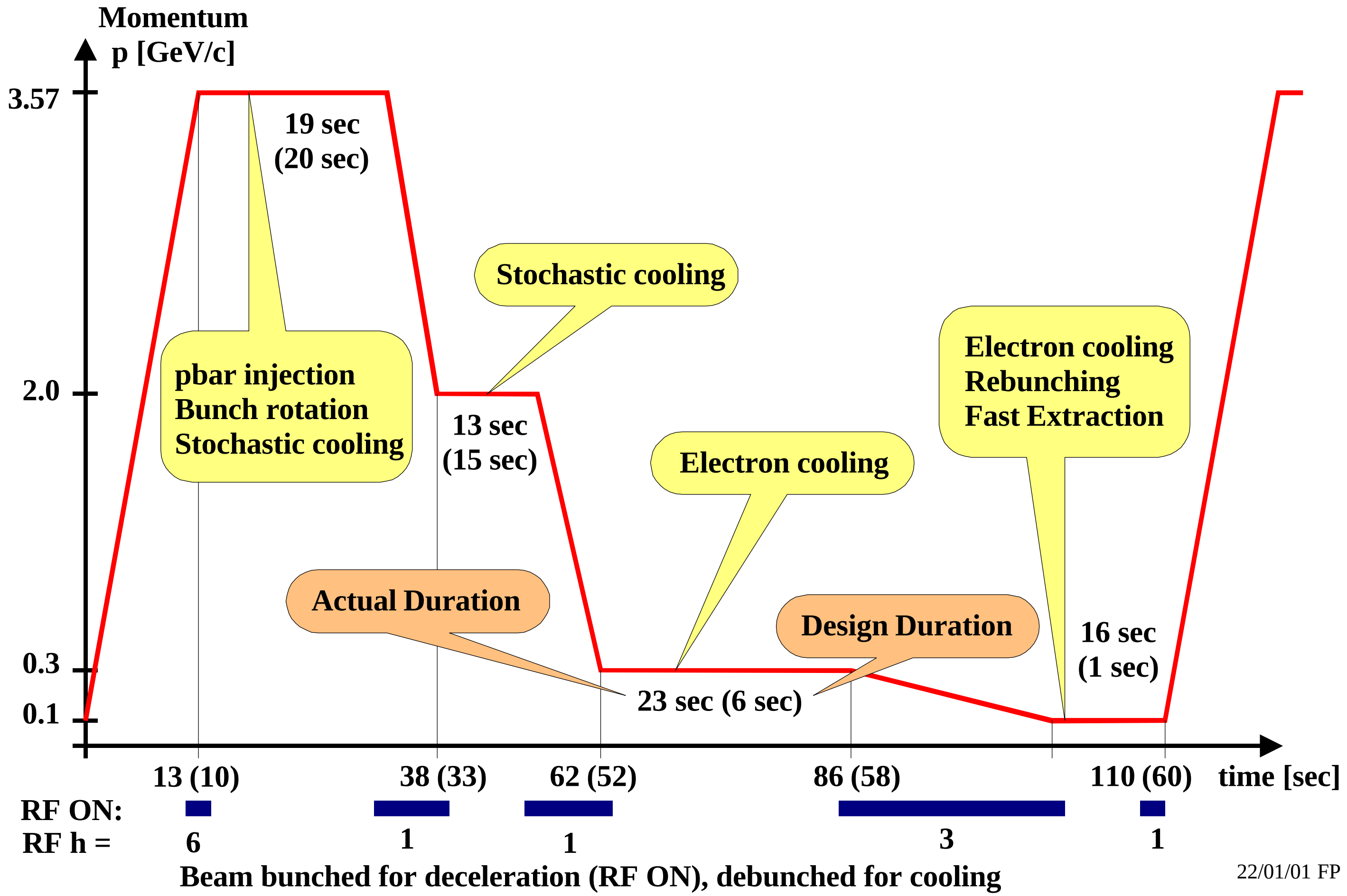
An *economic* pbar source

- One ring (AD) with pbar's in stead of four: AC, AA, PS, LEAR.
- Power consumption ~8 MW => ~0.5 MW. No more 3.57 GeV/c storage rings in CW!
- Re-use 90 % of AC equipment: magnets, RF, stochastic cooling. Recycle E-cooler from LEAR: ~80 MCHF machine for 8 MCHF
- Upgrade control system, vacuum system, power supplies, and beam diagnostics. Exper. area.

AD Ring and Hall



AD deceleration cycle



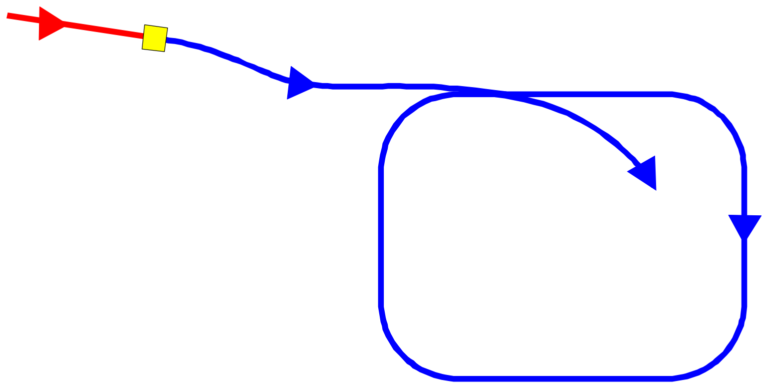
Stochastic Cooling

- Only band I (1 - 1.6 GHz) from AC used
- Initial commissioning in protons direct mode
- Design performance quickly achieved (speed, emittances)
- Careful attention to common mode performance of transverse pick-ups ***and*** kickers to avoid degrading longitudinal performance
- Cooling at 2.0 GeV/c was mainly required to get small E_L (get away from transition to get larger η)
- Some optimization for the stacking mode (gain, cooling time) needed to improve stacking efficiency

Electron Cooling

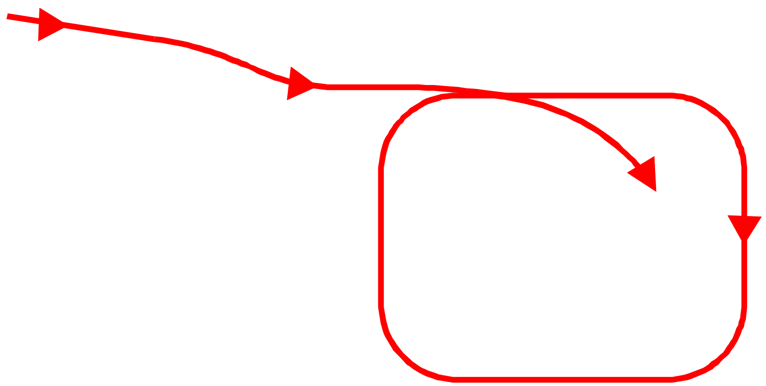
- In 1999 we suffered a lot from poor alignment of e-cooler
- Orbit kicks from toroids guide field could not be corrected due to inadequate strength of compensating correctors: power supplies upgraded in 2000.
- Coupling introduced by e-cool solenoid is compensated by compensating solenoid and two skew quads. Good agreement in proton direct mode. Poor agreement in pbar mode (normal magnet polarity). ?????
- Cooling is much slower than anticipated, especially at 100 MeV/c. Large initial transverse emittances contributing factor.

AD Modes: pbar mode



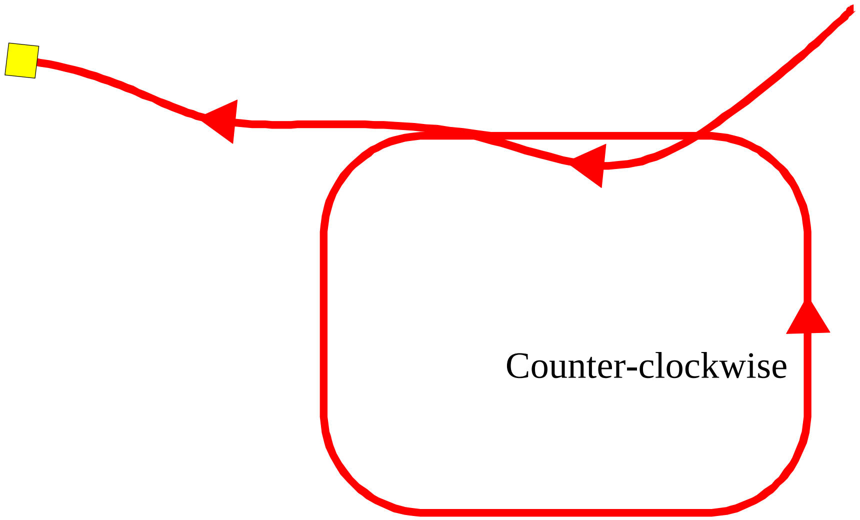
- Normal operation, low intensity pbars: 10^7 - 4 10^7
- Difficult beam diagnostics (tunes, intensities, orbits..)
- Each phase plane (E_H, E_V, E_L) must be compressed ~5000 times (six-dimensional phase space density increased 10^{11} !!!)
- With *improved beam diagnostics*, most setting up can now be done in this mode
- Access to experimental hall OK

AD Modes: protons direct



- Used for initial setting up of stochastic cooling and electron cooling at 300 MeV/c
- Intensity typically 2 10^9 (limited by stochastic cooling speed)
- DC beam transformer works (marginally)
- Magnetic fields does not re-produce when inverted (ex. Coupling)
- No access to hall

AD Modes: protons via loop



- No cooling possible with CCW rotation: very dense injected beam required
- Intensity typically 5 10^9 (limit: transverse mode coupling instabilities)
- Tune measurements at low energy difficult due to $\Delta p/p$
- Difficult to correct and maintain small injection oscillations
- Large E_H blow-up due to mismatch: source unknown!
- Used for set-up of ‘dog-leg’ transport
- No access to experimental hall

Commissioning Challenges

- Design report: start commissioning 9/98, physics start 7/99
- Actual schedule: start 10/98, physics start 7/00.
- *Why so much longer than anticipated?*
- Quality control problems during installation:

i) e-cooler (mis-) alignment

ii) pick-up alignment relative to quads

iii) inadequate strength of e-cool horizontal correctors

iv) intermittent triggering of key timing pulse: restart all magnet GFA's (many receivers, many sources). 25 ohm termination!

Commissioning Challenges

- Bad surprises:

i) moving coils in wide quadrupoles => loose shims

ii) broken cooling water pipes due to moving coils

iii) Orbit fluctuations: moving coils? Power supplies?

iv) Bug or feature? Missing timing pulses if moved across basic period boundary. Had to use standard CO hardware for very long cycle...

v) field lag compensation of slow eddy current effects (10 - 20 seconds) on flat tops required

vi) Poor tracking of QDC53 with other QDN's: QTRIM5 supply introduced

vii) New transverse LF Schottky pickup 6 - 8 dB higher noise than anticipated (cause unknown). Transverse Schottky below noise threshold.

Commissioning Challenges

- Bad surprises (cont.)

viii) It was *pretty worrying* that it was only in June 2000 (20 months after commissioning start!!) that we got enough beam *of any sort* down to 100 MeV/c to even try setting up e-cooling at this energy

ix) From July to September 2000, the transfer efficiency of the 100 MeV/c extraction line fluctuated a factor 2 - 3. Bad beam trajectory between kicker and septum

x) There was a harmful interference from the residual noise of the C02 RF system on the longitudinal Schottky signals between 1 - 2 MHz

Commissioning Challenges

- Good surprises:

i) ultra-low noise orbit system could be improved to +/- 0.2 mm precision at 2 10^7 after EMC clean-up (50 dB immunity gained) during 1999/2000 shutdown

ii) Longitudinal LF Schottky pick-up (0.3 - 30 MHz) worked as anticipated. Bunched beam intensity from RF currents (f_{rf} and 2 f_{rf}) and longitudinal Schottky measurements delivered by DSP system

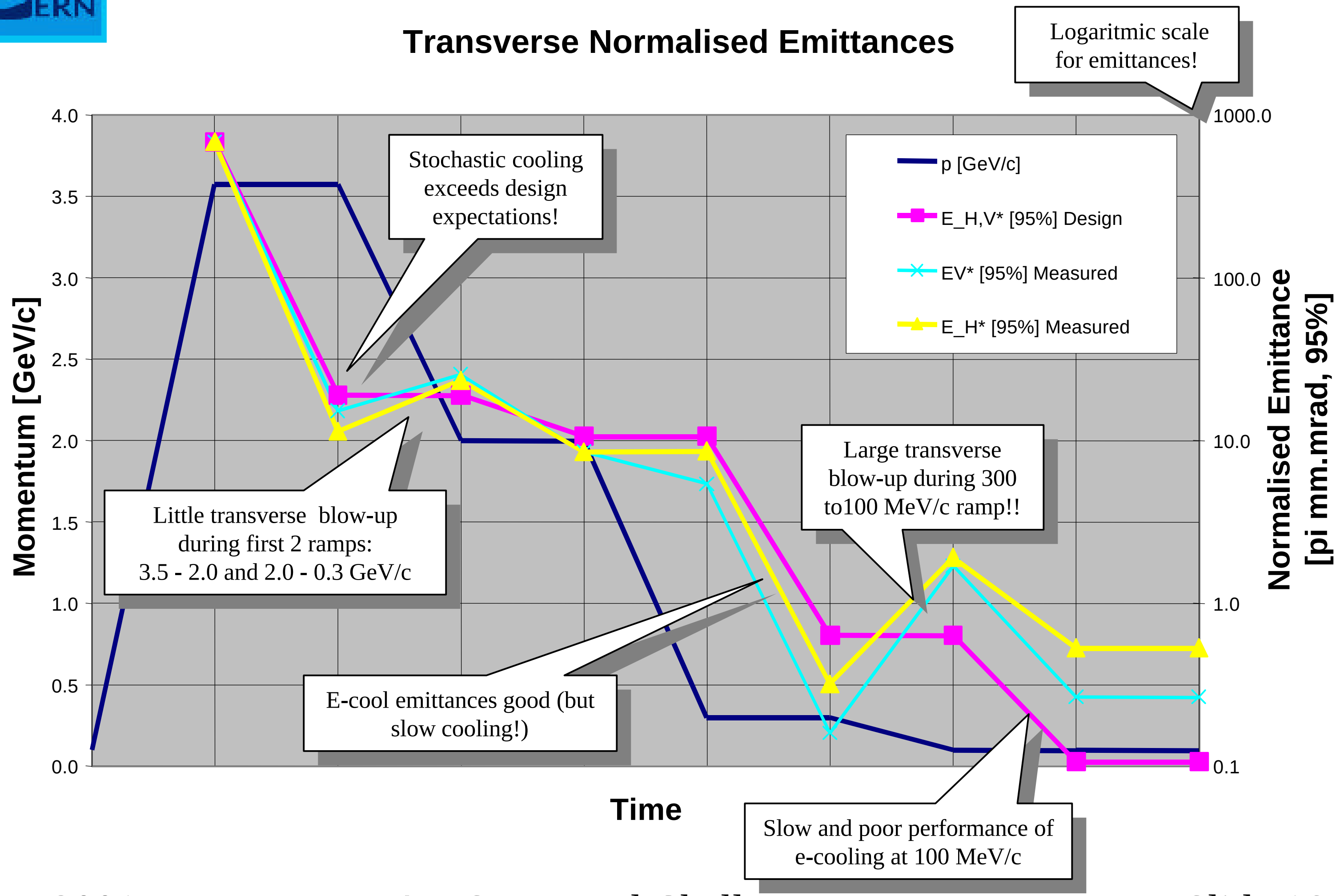
iii) Response matrix measurements very useful in identifying ring optics and deviations from expected nominal optics and suggest corrections

iv) Improvements in beam diagnostics (orbits, tunes, coupling, intensities, response matrices) for typical pbar intensities (2 10^7) made it possible to make majority of setting up in pbar mode

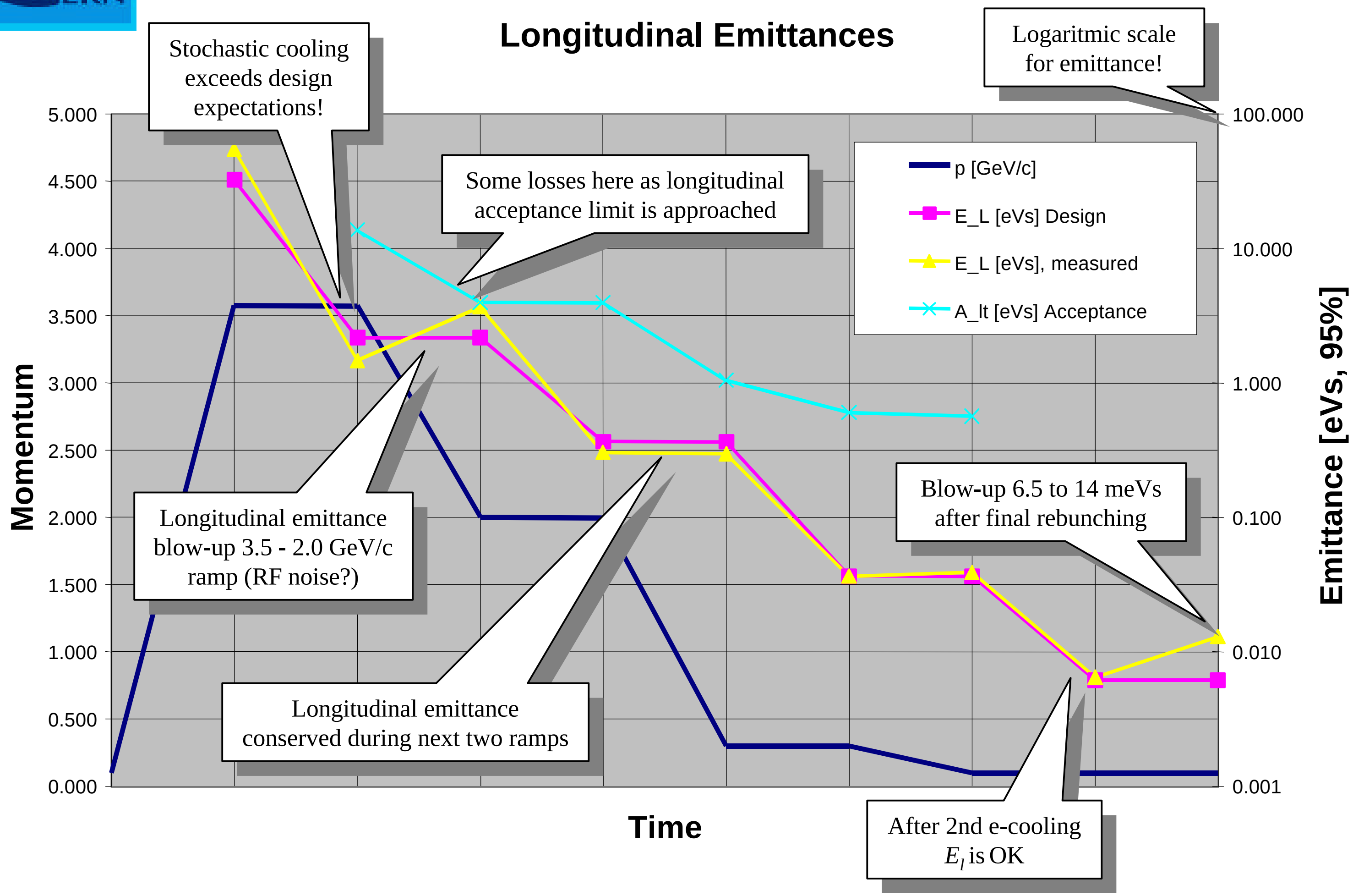
Present Performance

Extracted Beam		Obtained Nov 2000		Design
Momentum	☺	100 MeV/c		100 MeV/c
Intensity	☺	$2\ 10^7$ ($2.7\ 10^7$)		$1.2\ 10^7$
Cycle time		110 secs	☹	60 secs
E_H [95%]		$4\ \pi$	☹	$1\ \pi$
E_V [95%]		$2\ \pi$	☹	$1\ \pi$
Δp/p [95%] debunched	☺	$1.1\ 10^{-4}$		$1.0\ 10^{-4}$
Δp/p [95%] bunched		$1.3\ 10^{-3}$	☹	$1.0\ 10^{-3}$
Δp/p [95%] after bunch rot		$2.3\ 10^{-3}$	☹	$1.0\ 10^{-3}$
Bunch length [95%]		590 ns	☹	500 ns
With bunch rot. [95%]		330 ns	☹	200 ns

Transverse Performance



Longitudinal Performance



Remaining Issues and Improvements

- Understand mysterious vertical kick 5 ms before extraction??
- Improve efficiency of 9000 line: Efficiency 80% => ~98 %, Caused by $> 2 \times E_H$ blow-up at PSB-PS injection at 1.4 GeV. Excessive irradiation of 9000 line (NOT radiation hard).
- Combine USY410x pick-ups for 20 kHz - 30 MHz bandwidth. Bunched beam intensity measurement at h = 1 @ 100 MeV/c (174 kHz). TFA7049 commissioning (7000 line and Asacusa?)
- Applications program upgrade for RF cycle editor and Schottky signals. BTF extension of DSP system
- E-cooling: Understand strange behaviour of solenoid compensators. Still marginal horizontal corrector dipoles. Slow 100 MeV drift feedback. Non-zero dispersion optics.

Remaining Issues and Improvements (cont)

- Reduce longitudinal emittance blow-up:
  - extraction rebunching: 6.5 - 14 meVs,
  - 3.5 - 2.0 GeV/c blow-up and losses
- Reduce transverse blow-up 300 MeV/c - 100 MeV/c.
  - Resonances?
  - Tunes?
- Improve efficiency of stacking mode, presently only ~65% for 3 shots stacked

Conclusion

- The AD was a challenging project. Marginal resources, and with an ambitious goal. The commissioning phase was even more challenging!
- But suddenly (July 2000) we did finally succeed in getting this big 'bricolage' to work respecting the good CERN tradition of successful projects. But some of us were worried….
- Many service groups (especially LHC/VAC, PS/BD, PS/PO and PS/CO) attacked the challenging specification with great competence. Thanks to them all!