High Beam Intensity Effects in PEP-II

U. Wienands, PEP-II Run Coordinator

for A. Kulikov.

Acknowledgments: R. Holtzapple, F.-J. Decker, W. Kozanecki, J. Seeman, M. Pivi, Y. Cai

Outline of Talk

- Vacuum system parameters
- Scrubbing experience
- Multipactor effects: pressure rises
- Effects on luminosity & beam-pattern effects
- Summary

PEP-II Beam Parameters

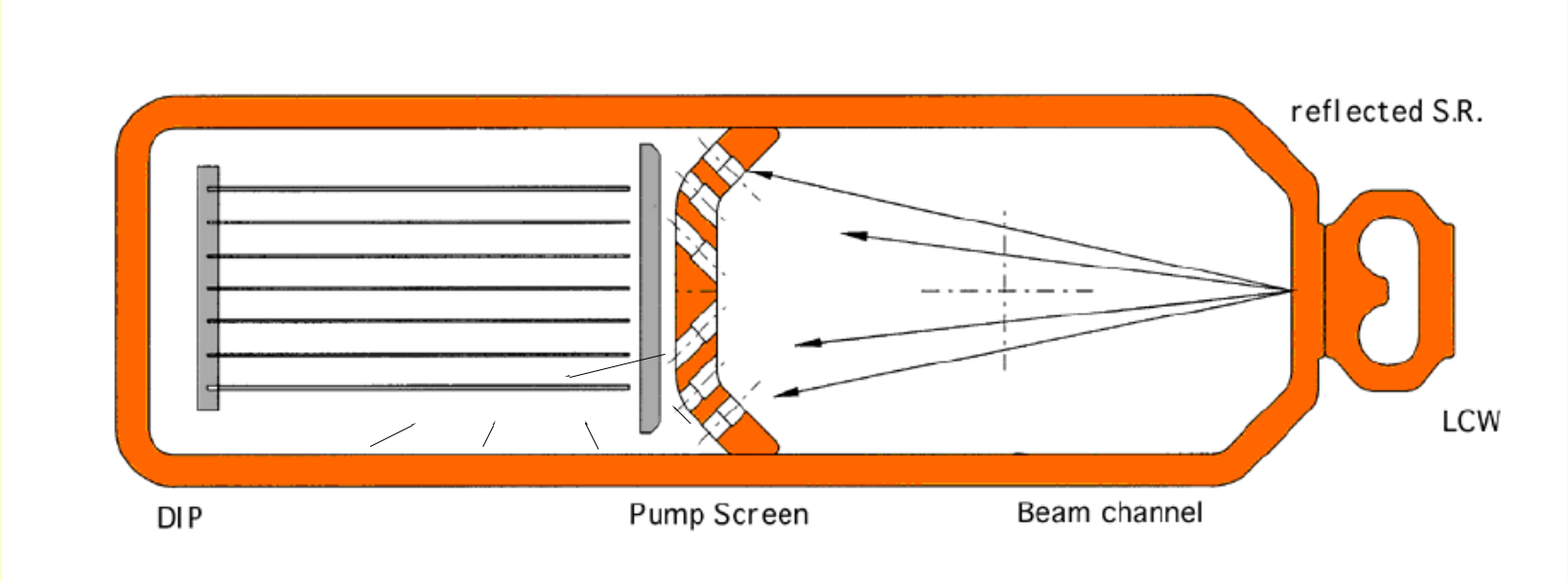
	LER(e^+)	HER(e^-)	
E	3.1	9	GeV
Beta x	50	28	cm
Beta y	1.26	1.2	cm
Emit x	30	49	πnmr
Emit y	1	2	πnmr
N_{bunch}	1230		
l_{bunch}	1.1	1.3	cm
I_{tot}	1700	1150	mA
N	8.3	5.6	E+10/bunch

PEP Vacuum System Parameters

Parameter	LER	HER
Beam current	2.14 A	0.95 A
Total rad. power	1.3 MW	3.5 MW
Power density	6.8 kW/γ-stop	35 kW/m
Pumping in arcs	2000 l/s/stop TSP	120 l/s/m DIP
Pumping, straights	19×400 l/s	19×400 l/s
Arc pressure at 3 A	< 3 nTorr	< 3 nTorr
Straight press., 3 A	< 10 nTorr	< 10 nTorr
IR2 pressure at 3 A	< 1 nTorr	< 1 nTorr

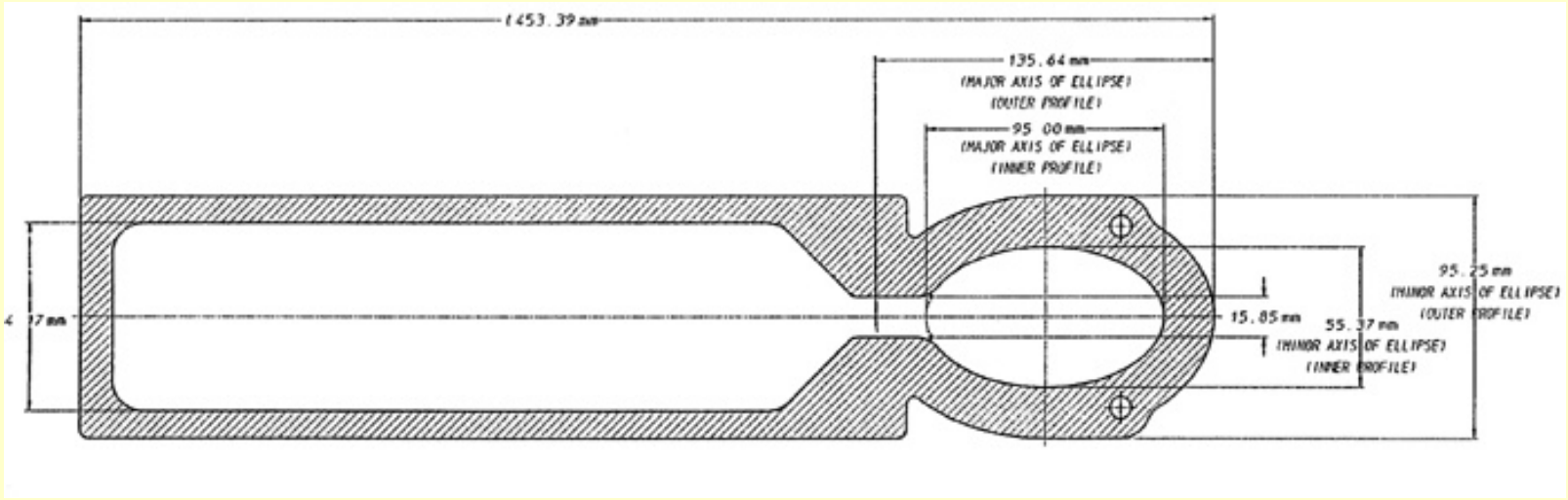
HER Arc Vacuum System

Cu extrusion with photon stop along outside,
distributed ion pumps in dipole field (DIPs)
baked & gdc before installation



LER Arc Vacuum System

Al extrusion, TiN coated,
with antechamber for synchrotron radiation,
discrete photon stops with localized Ti sublimation pumps
baked & gdc before installation

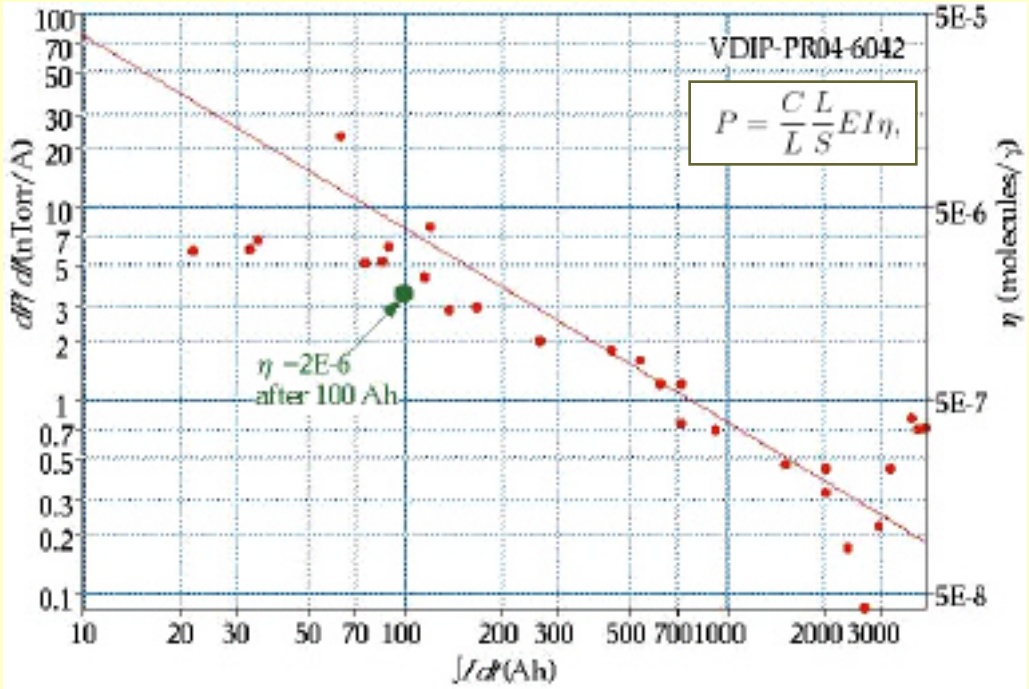


PEP II HER and LER

Straight-Section Solenoid

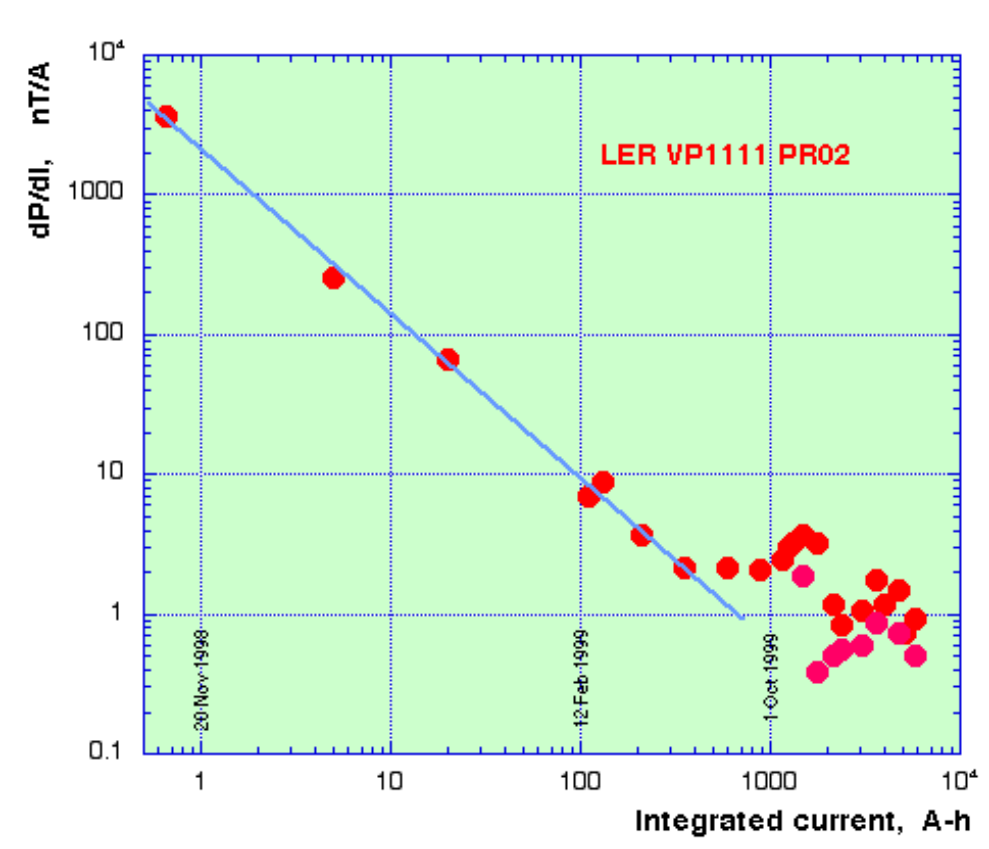
Scrubbing of the HER System

- The HER system has scrubbed as predicted in the CDR
  - Photon desorption coefficient $\eta \leq 2E\text{-}6$ achieved after 200 Ah exposure



Scrubbing of the LER System

- Despite the discrete photon stops, the LER has scrubbed at a similar rate as the HER.



Pressure *vs* Beam Current

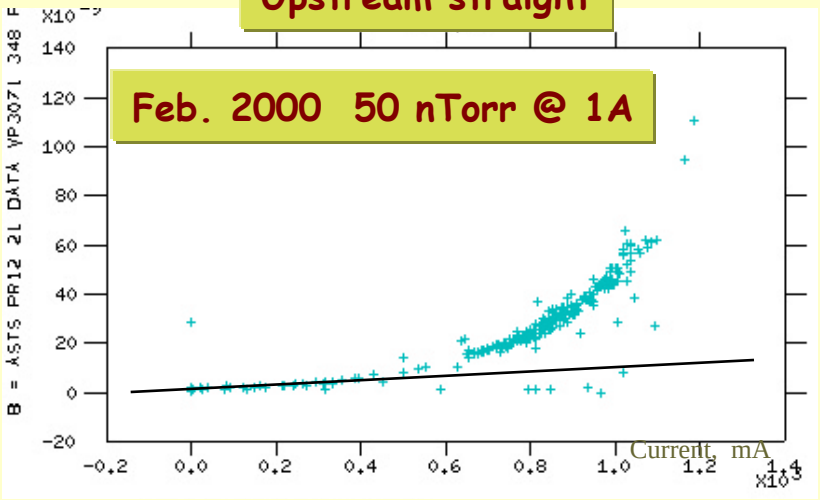
- Nonlinear pressure rise with beam current has been seen in the LER early on.
  - No such effect seen in the HER
- It is accompanied by a growth in beam size
  - in both planes
  - Horizontal growth seems specific to PEP, not seen in other e^+ machines.
- It is reduced with solenoidal magnetic fields.
  - Part of the pump current is due to electrons

PEP-II Solenoid Parameters

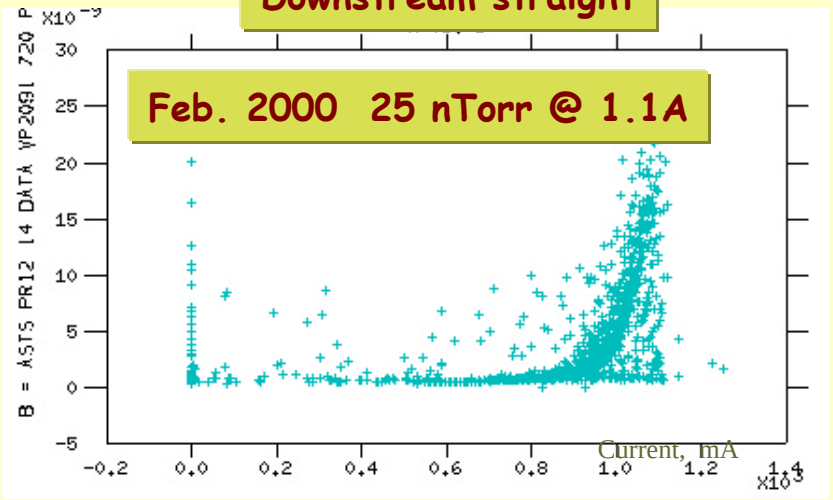
Parameter	LER Straights	LER Arcs
Chamber size (mm)	115 dia.	95x465
Wire gauge	#10	#10
Wire material	Cu	Cu
Wire package	Single cond.	Four cond. in parallel
Solenoid field (gauss/A)	2.4	0.57
Return wire	#10	#6
Power supply voltage (V)	30	200
Power supply current (A)	12	55
Max. Field (gauss)	29	31
Sol. length/pow. sup. (m)	10-15	80
Number of power supplies	54	12
Available drift length (m)	600	960
Soln. length installed (m)	600	960
Chamber material	SS	AL (TiN coating)

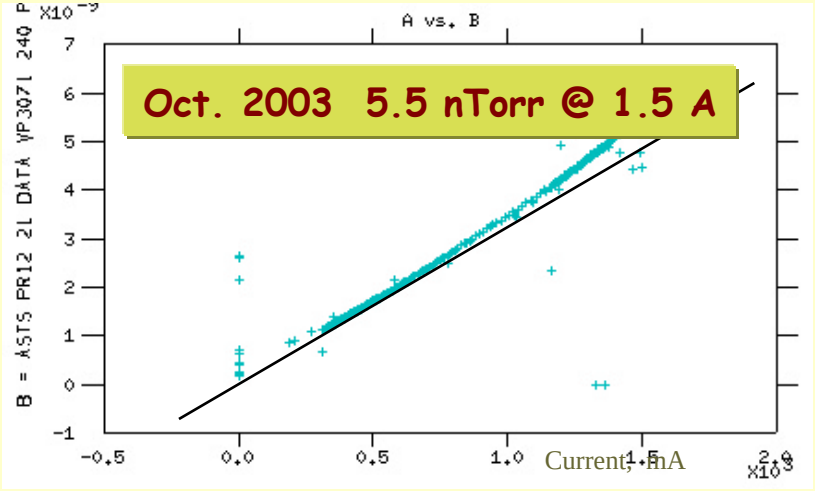
Electron multipacting in the LER straight sections.

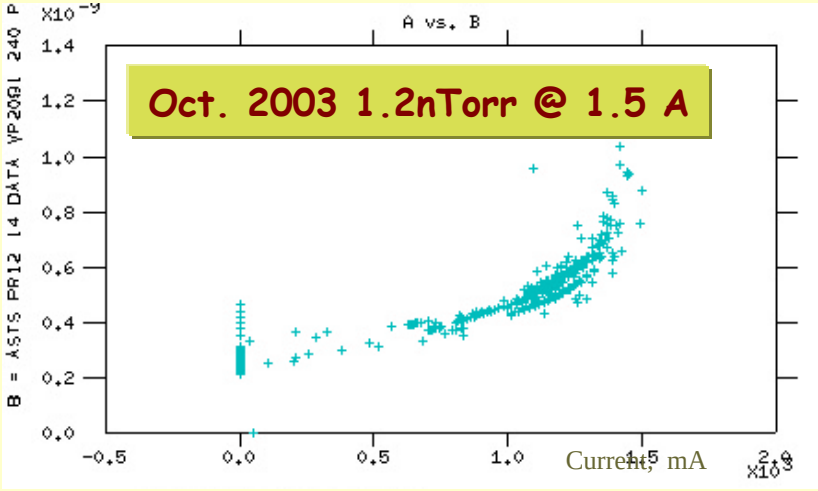
Upstream straight



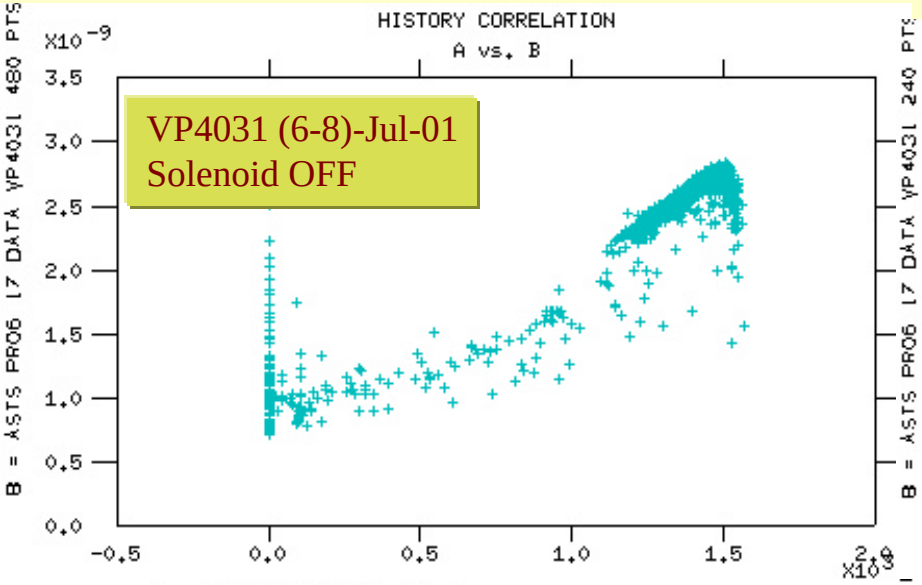
Downstream straight

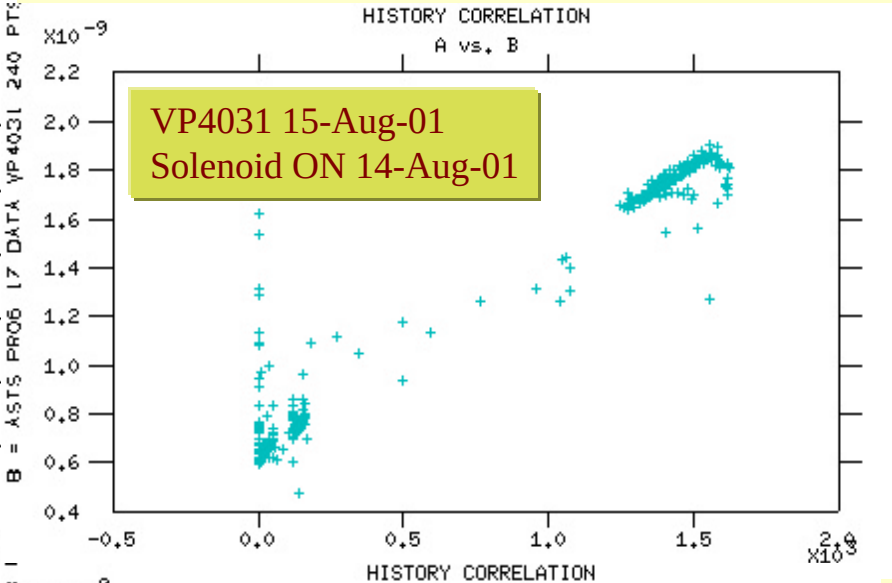


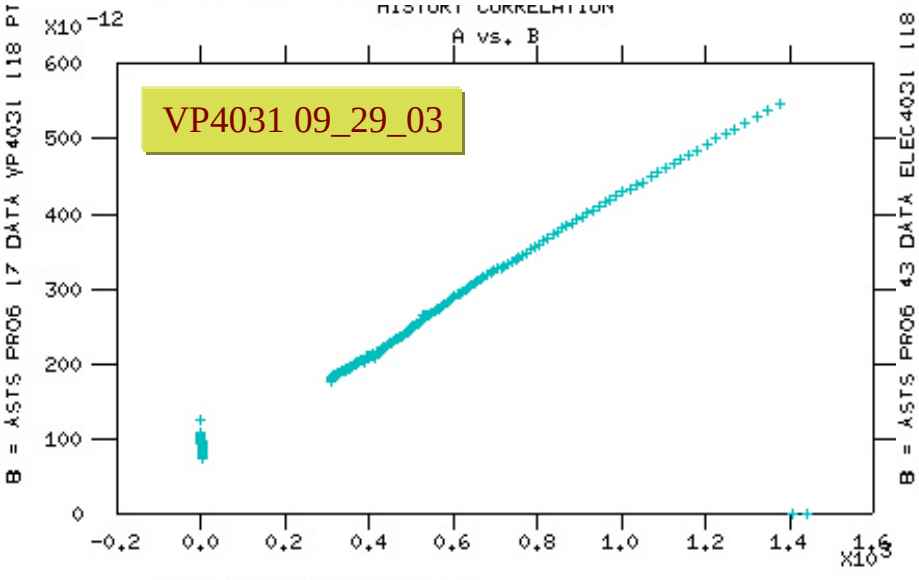


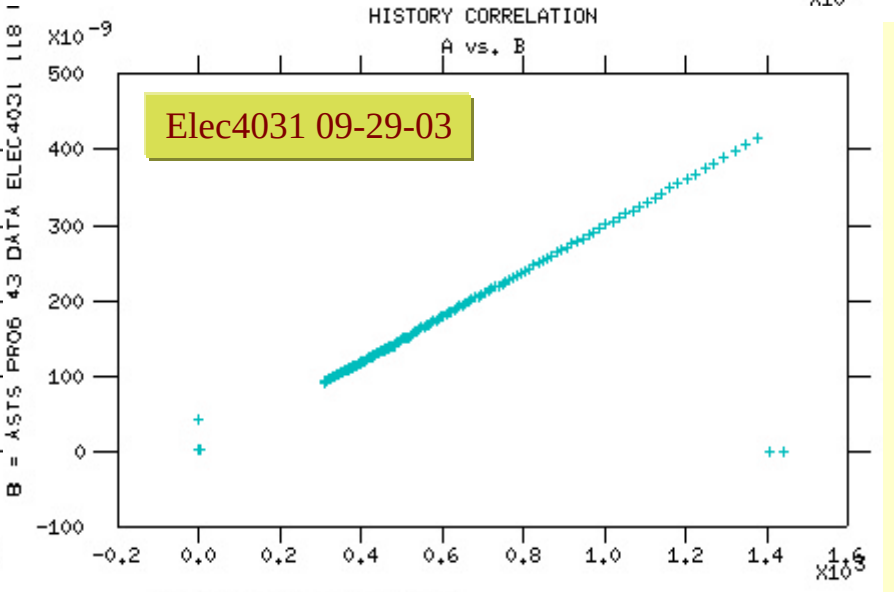


Electrons in the LER arcs



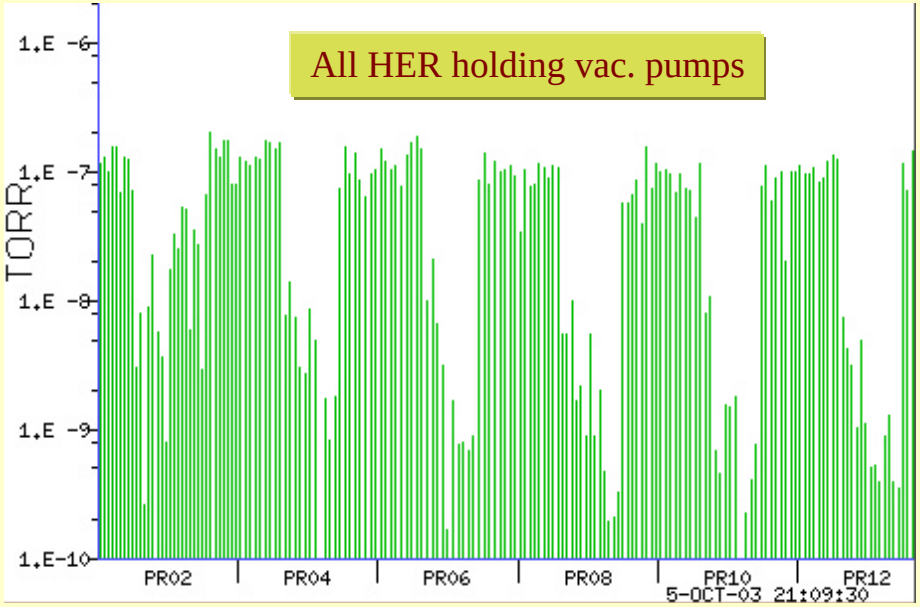




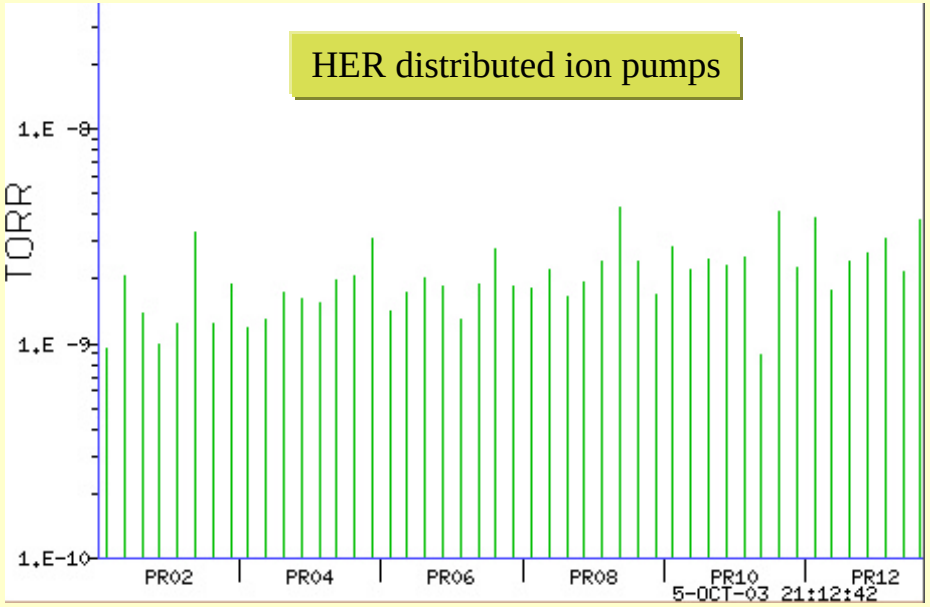


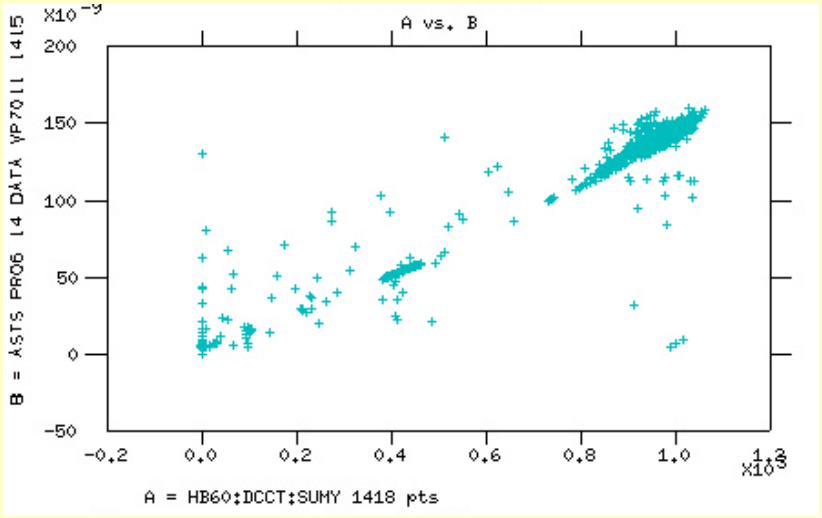
Electrons in the HER.

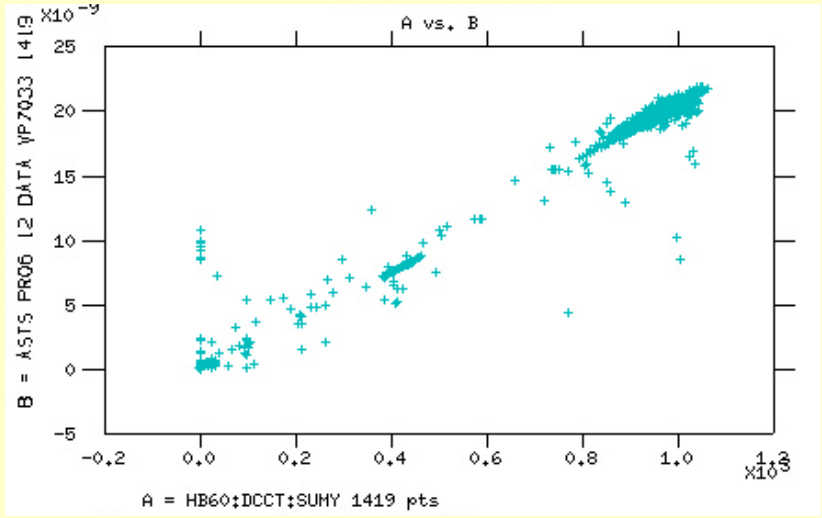
All HER holding vac. pumps



HER distributed ion pumps

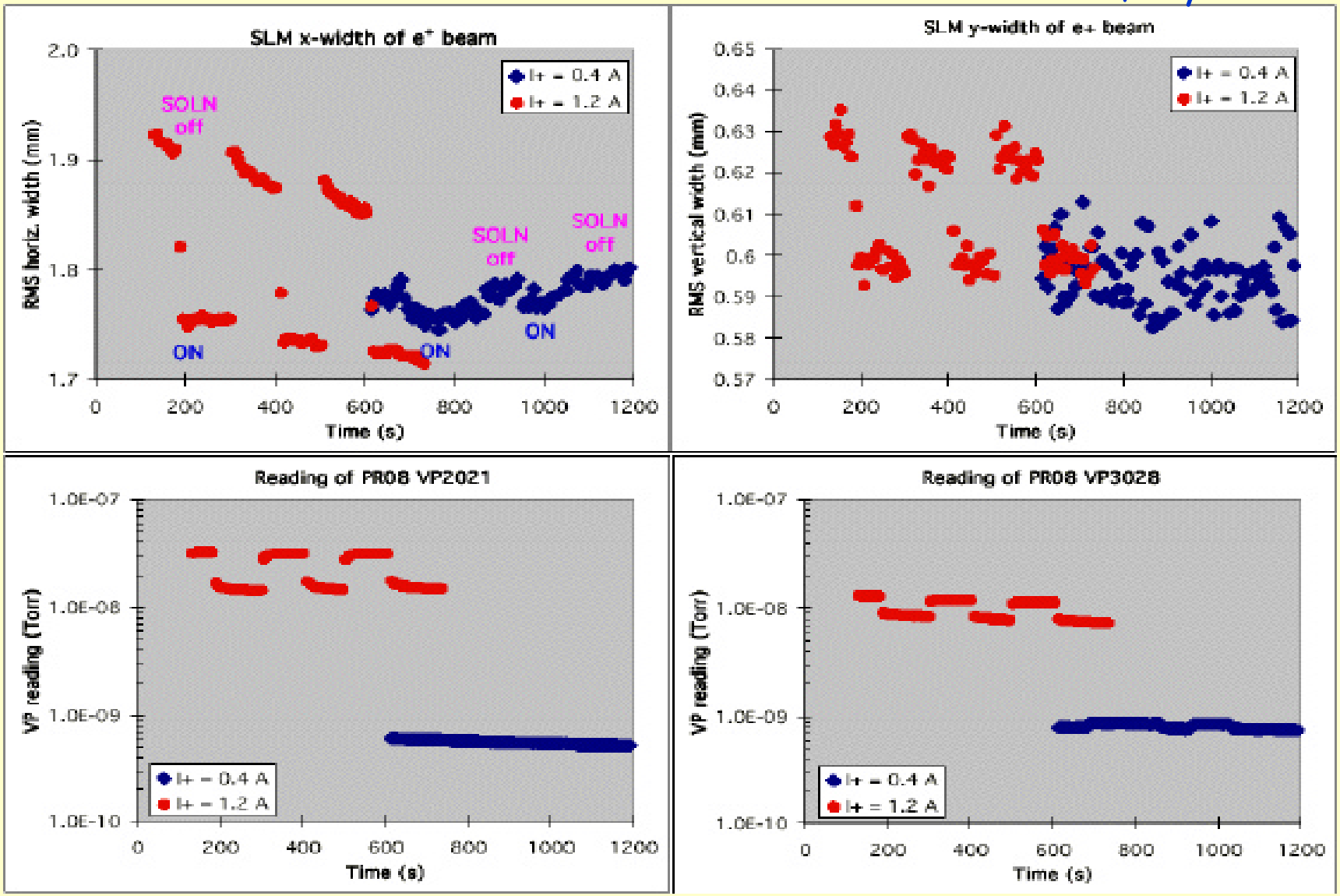






LER Beam Sizes Solenoid on/off

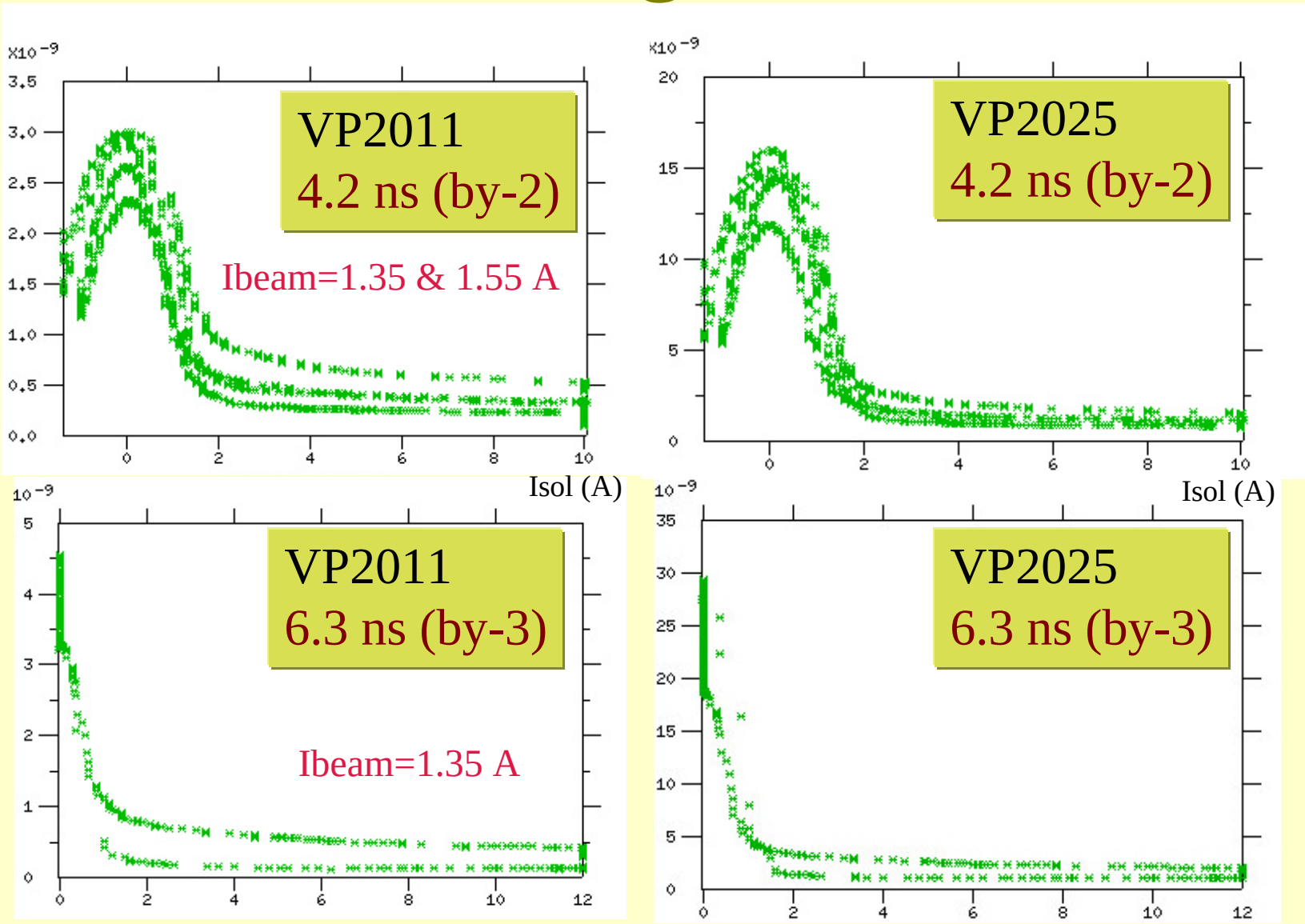
Kozanecki, Jly 2000



Pressure *vs* Bunch Spacing & Solenoid Current

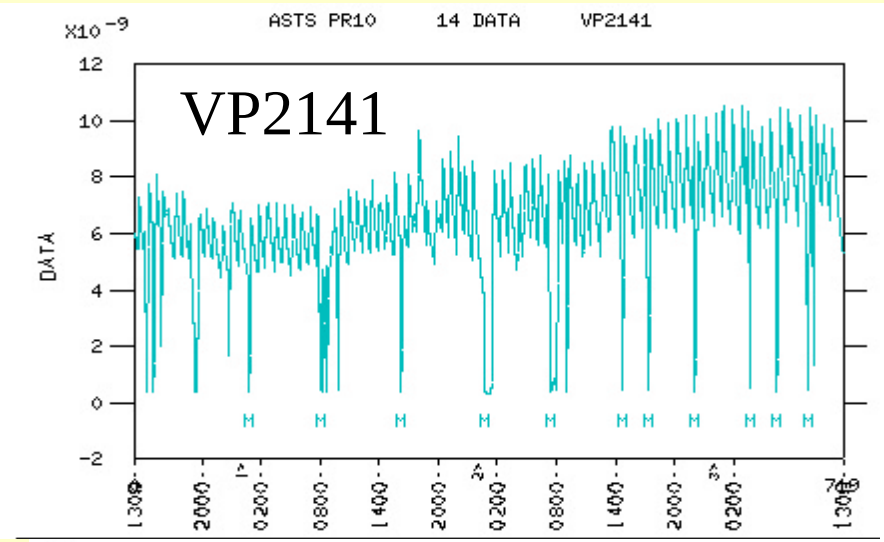
- 6.3 ns bunch spacing "flat" fill
- 4.2 ns bunch spacing with mini gaps
- Vary solenoid current setting
  - In Straight section 12
  - In Arc 7a: only 4.2 ns data, electron detector

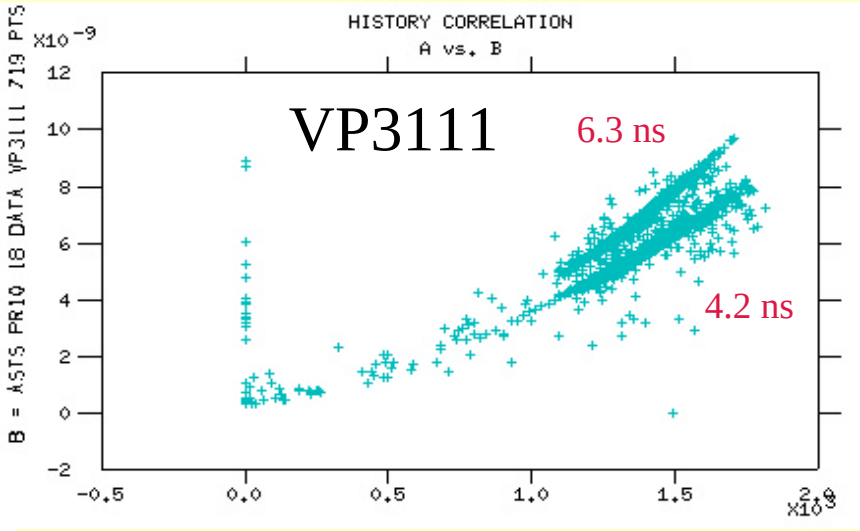
Straight 12

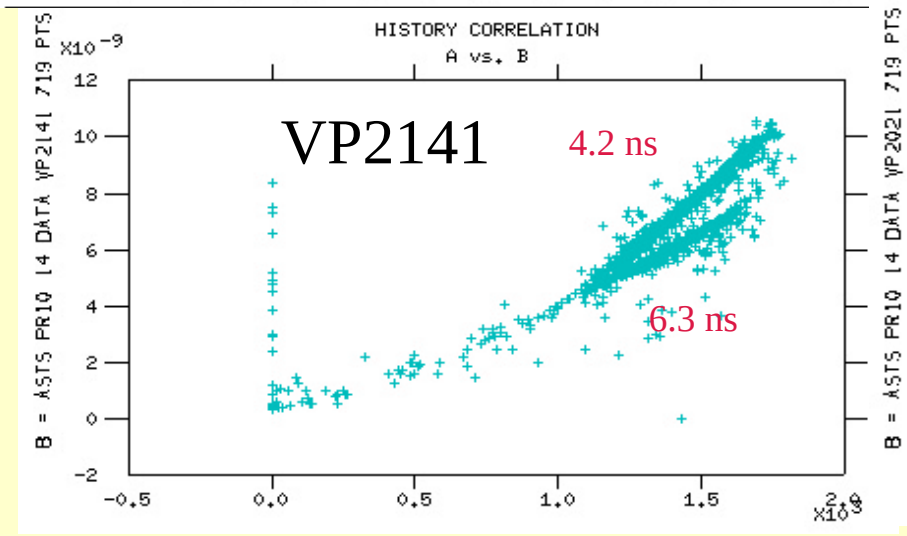

VP2011
4.2 ns (by-2)
Ibeam=1.35 & 1.55 A
Isol (A)
VP2025
4.2 ns (by-2)
Isol (A)
VP2011
6.3 ns (by-3)
Ibeam=1.35 A
VP2025
6.3 ns (by-3)

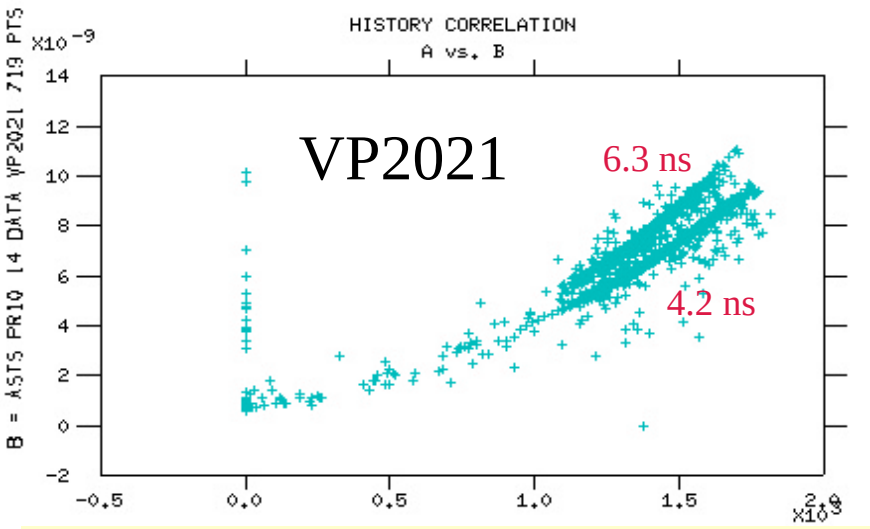
Str. 12 (cont'd)

6.3 ns (by-3) vs 4.2 ns (by-2) spacing: some go up, some go down…

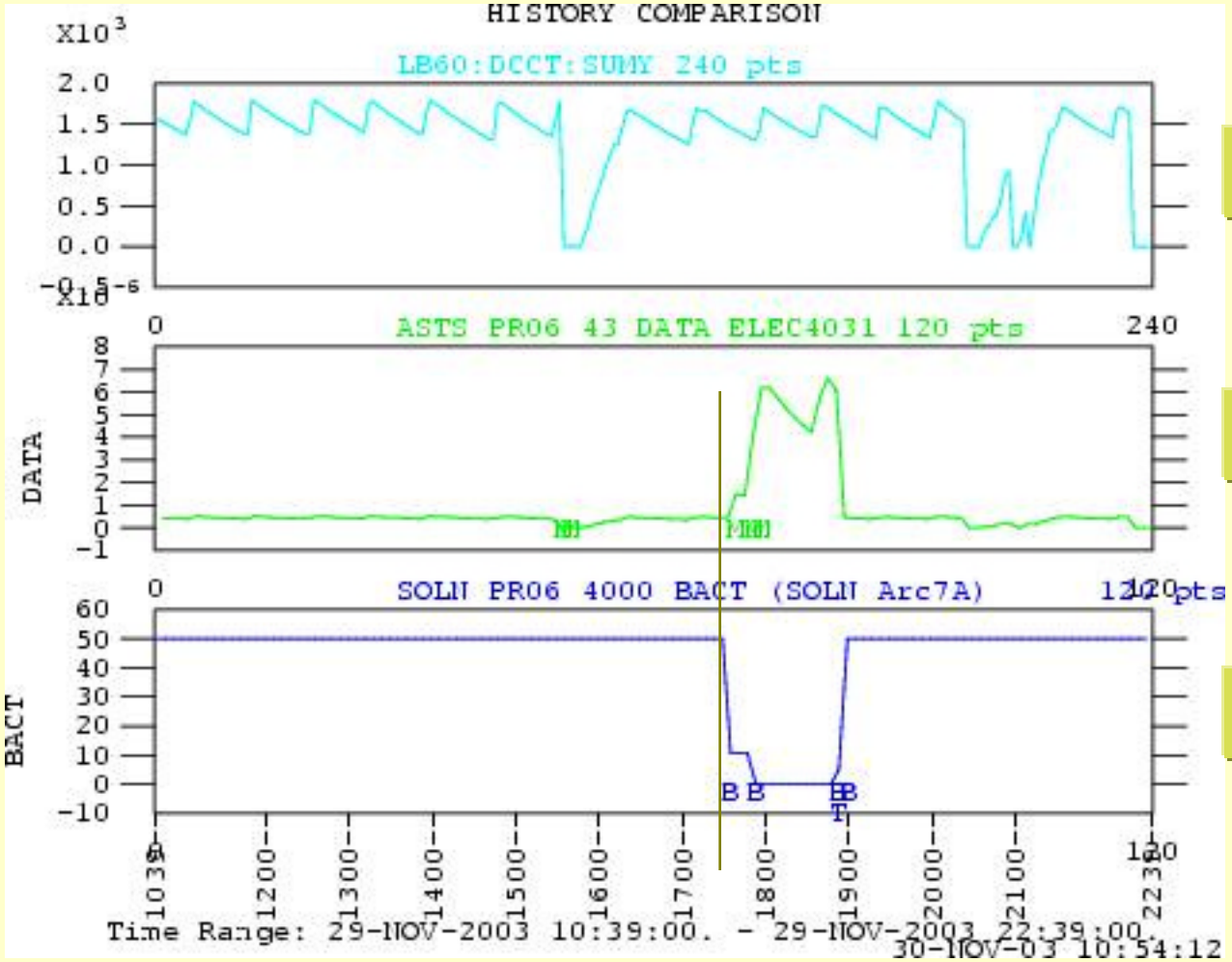








Solenoid on/off in Arc 7a



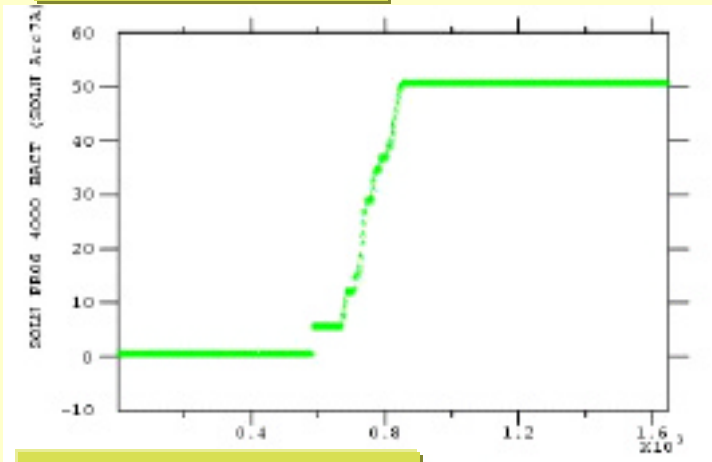
Beam current

e- detector (μA)

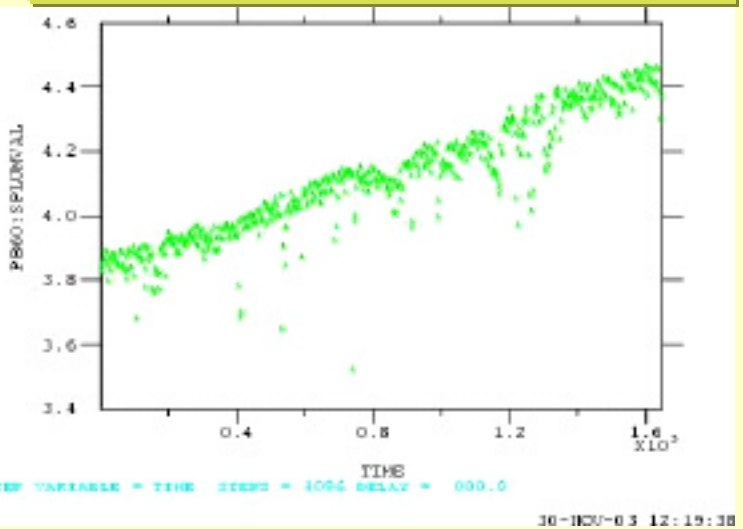
Sol. Current(A)

Solenoid on/off in Arc 7a (cont'd)

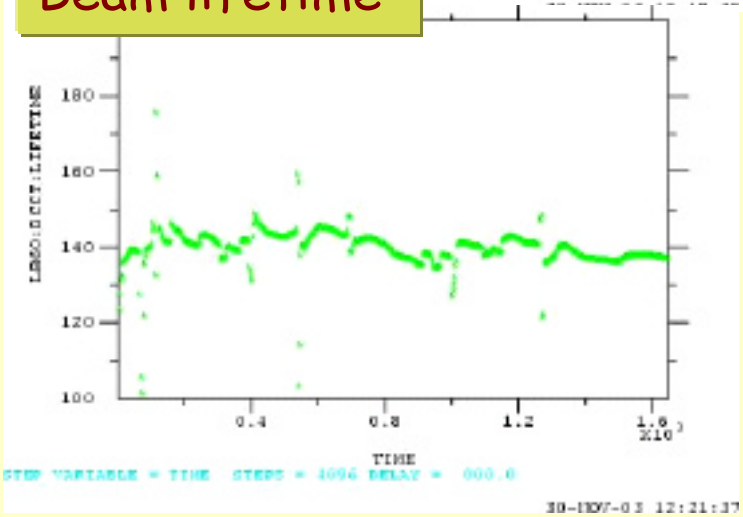
I_{sol} vs time



Spec. lumin. (≈ beam size)

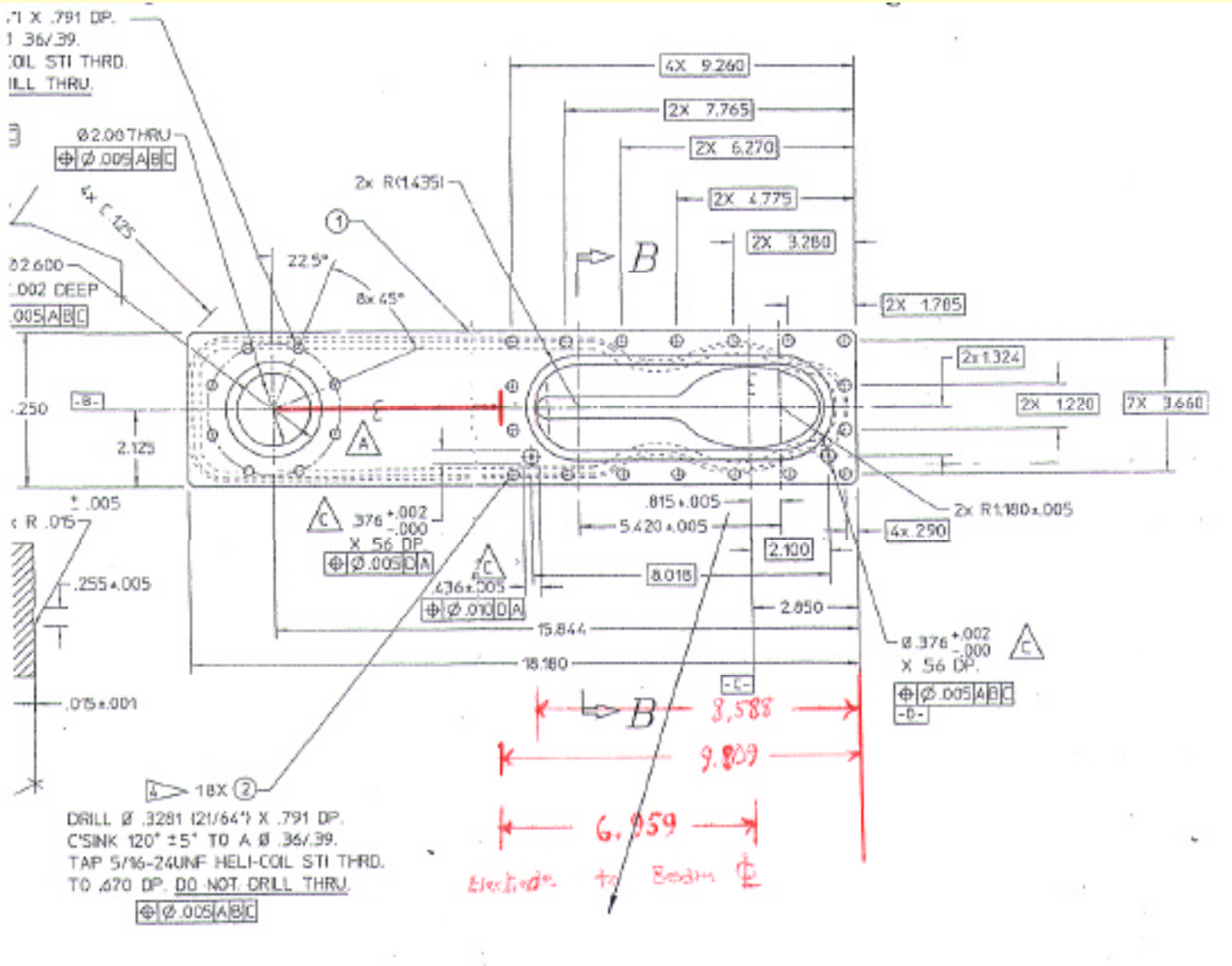


Beam lifetime

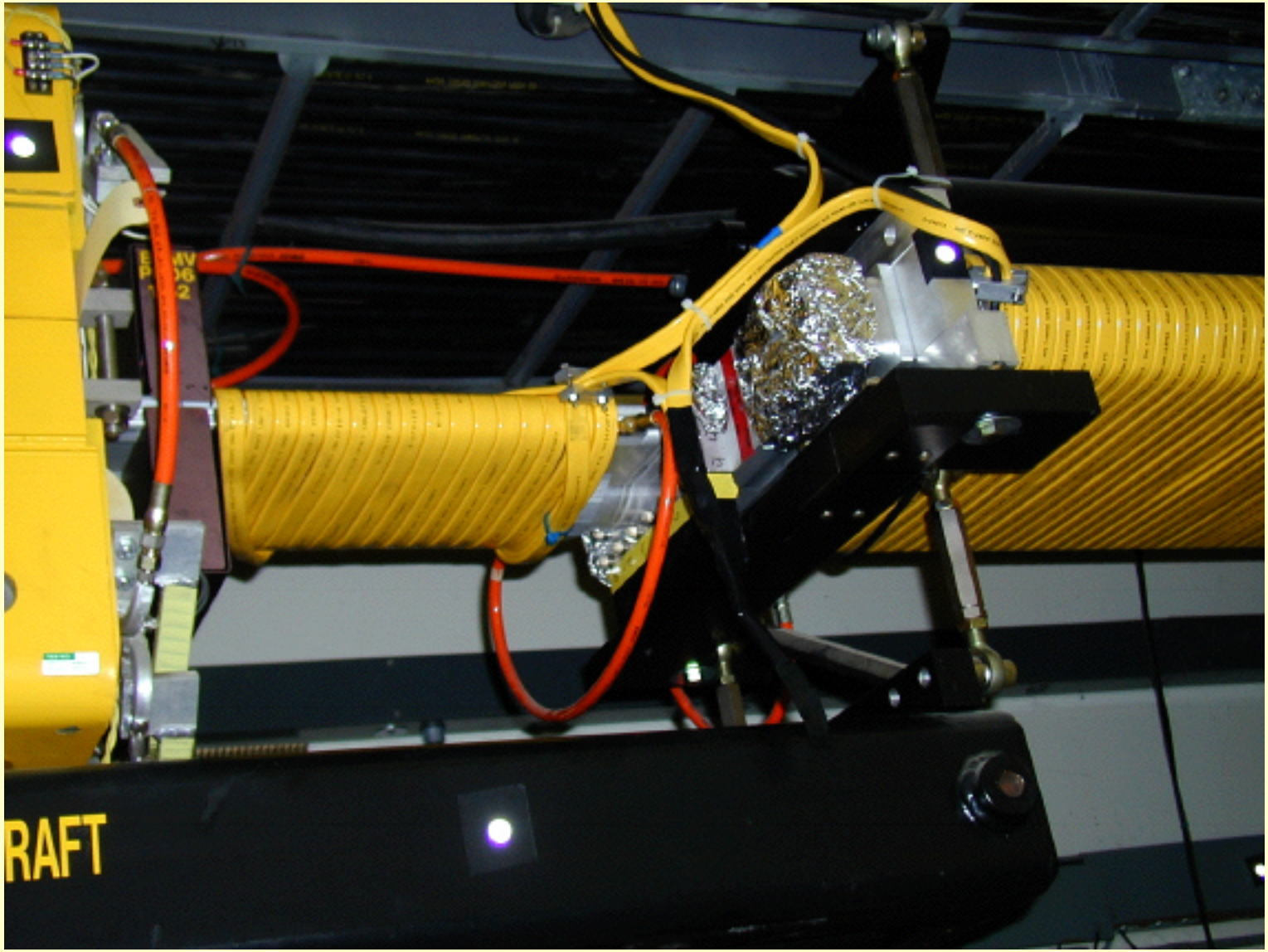


No measurable effect on beam lifetime and beam size.

Electron Detector



LER Arc Section w/o Sextupole



Pressure Measurements Summary

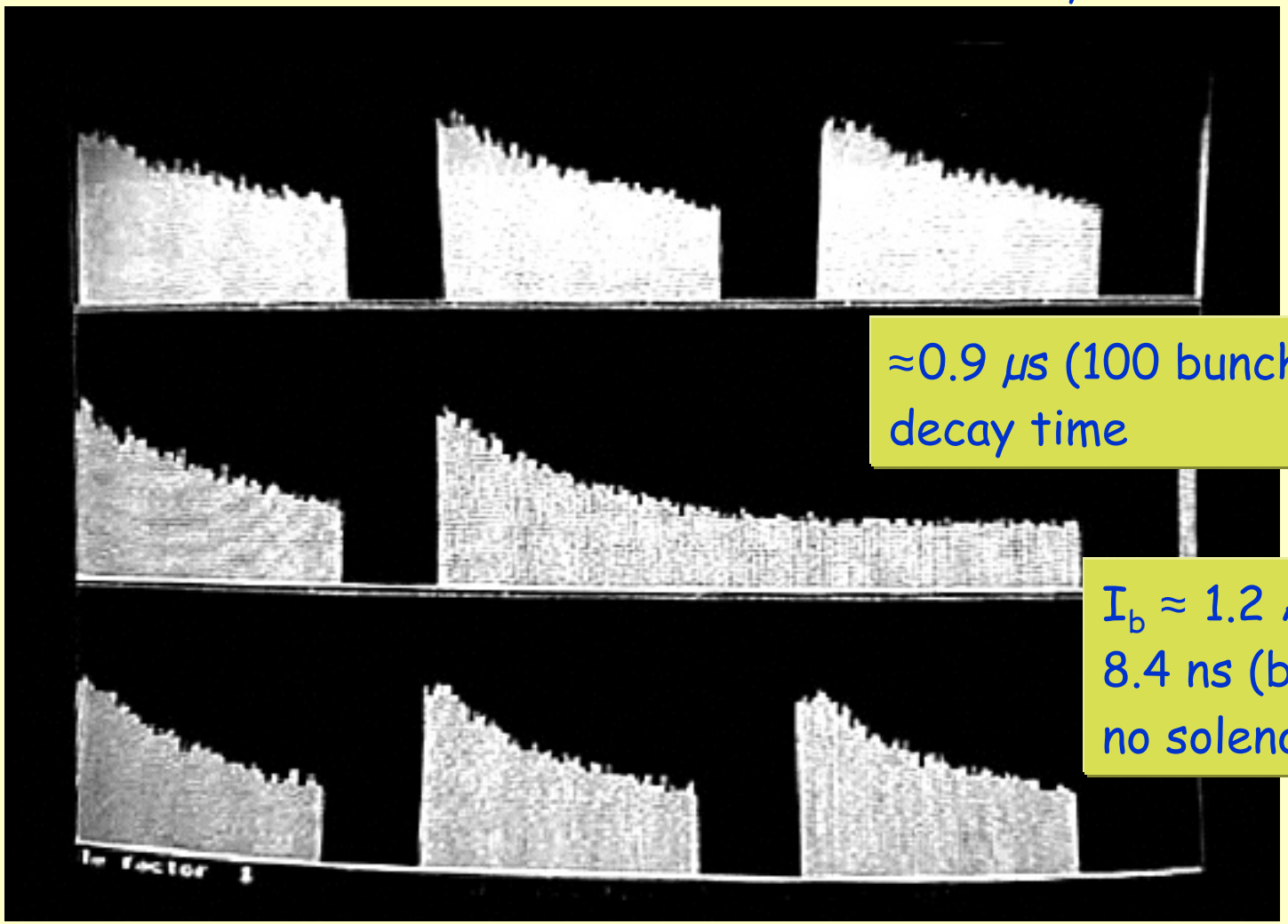
- With beam-pipe solenoids off, multipacting (still) seen strongly
  - Even after many kAh of s.r. scrubbing
- Beam size growth accompanies multipacting
  - "Electron-cloud effect"
- Apparent reduction of multipacting in 4.2-ns pattern
  - believed to arise from the mini gaps.

Electron Effect on Luminosity

- Effect of gaps in the fill
- Different bunch spacing
  - 4.2 ns vs 6.3 ns
- Future upgrades
  - Higher beam currents
  - possibly no more gaps in fill

Bunch-by-Bunch Luminosity

F.-J. Decker et al., ca. 2000

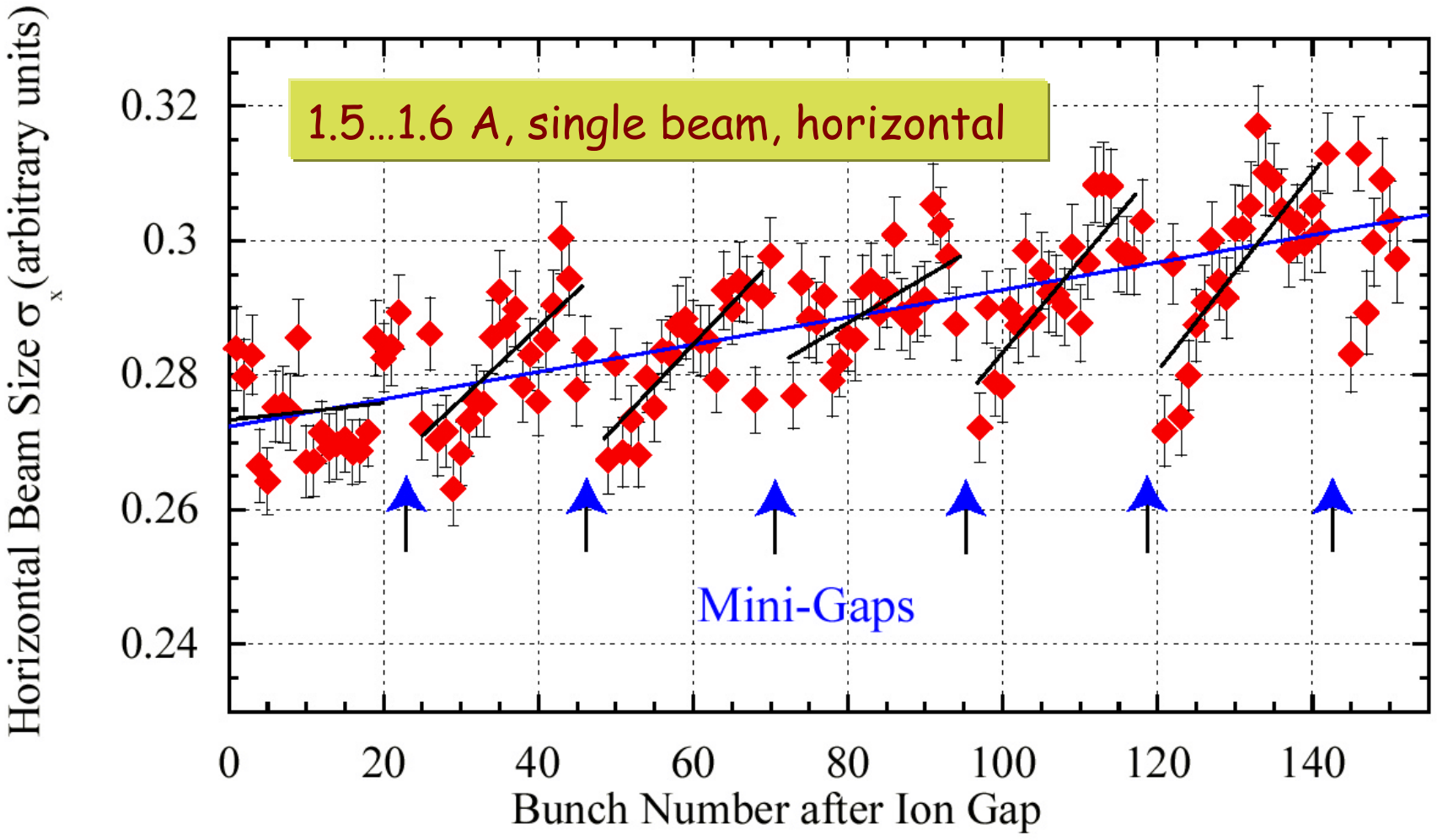


Fill Patterns with Mini Gaps

- The droop is caused by an increase in LER beam size
- Introducing gaps in the fill increases luminosity
- Gaps and solenoids to a large extent prevent beam-size increase at present conditions

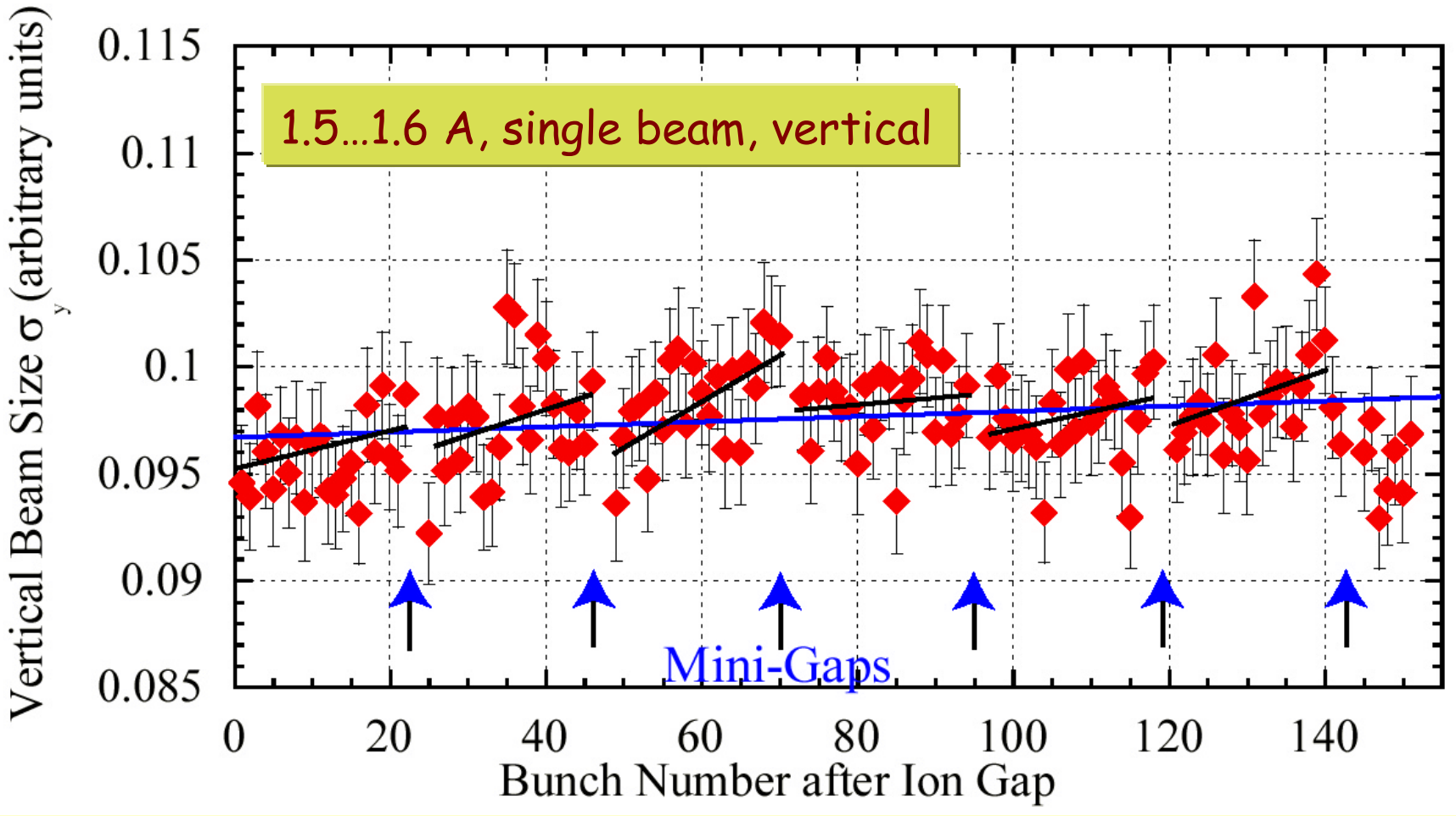
Gated Camera Measurements

R. Holtzapple et al., 2001



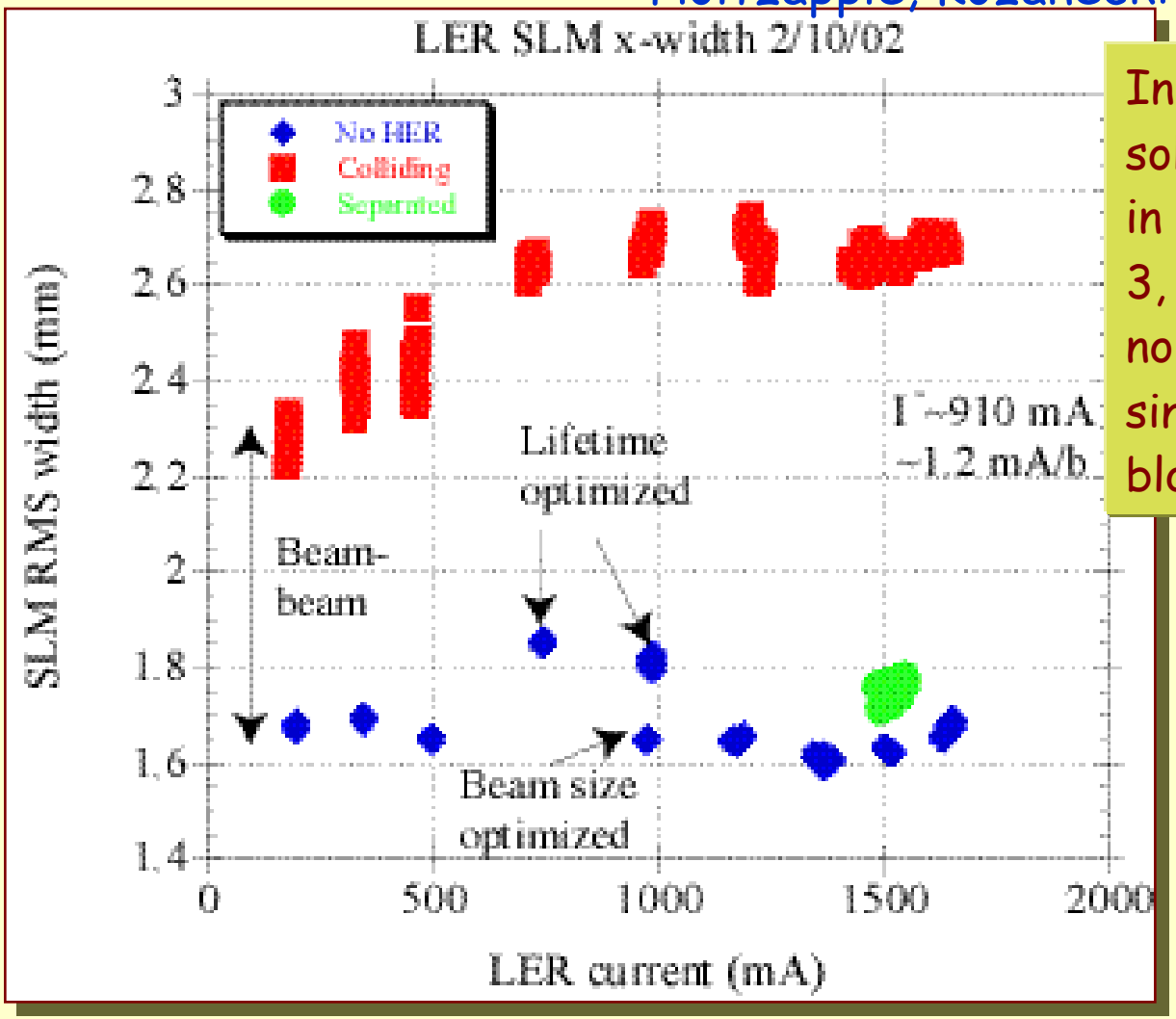
Gated Camera (cont'd)

R. Holtzapple et al., 2001



LER Beam Size/Physics Running

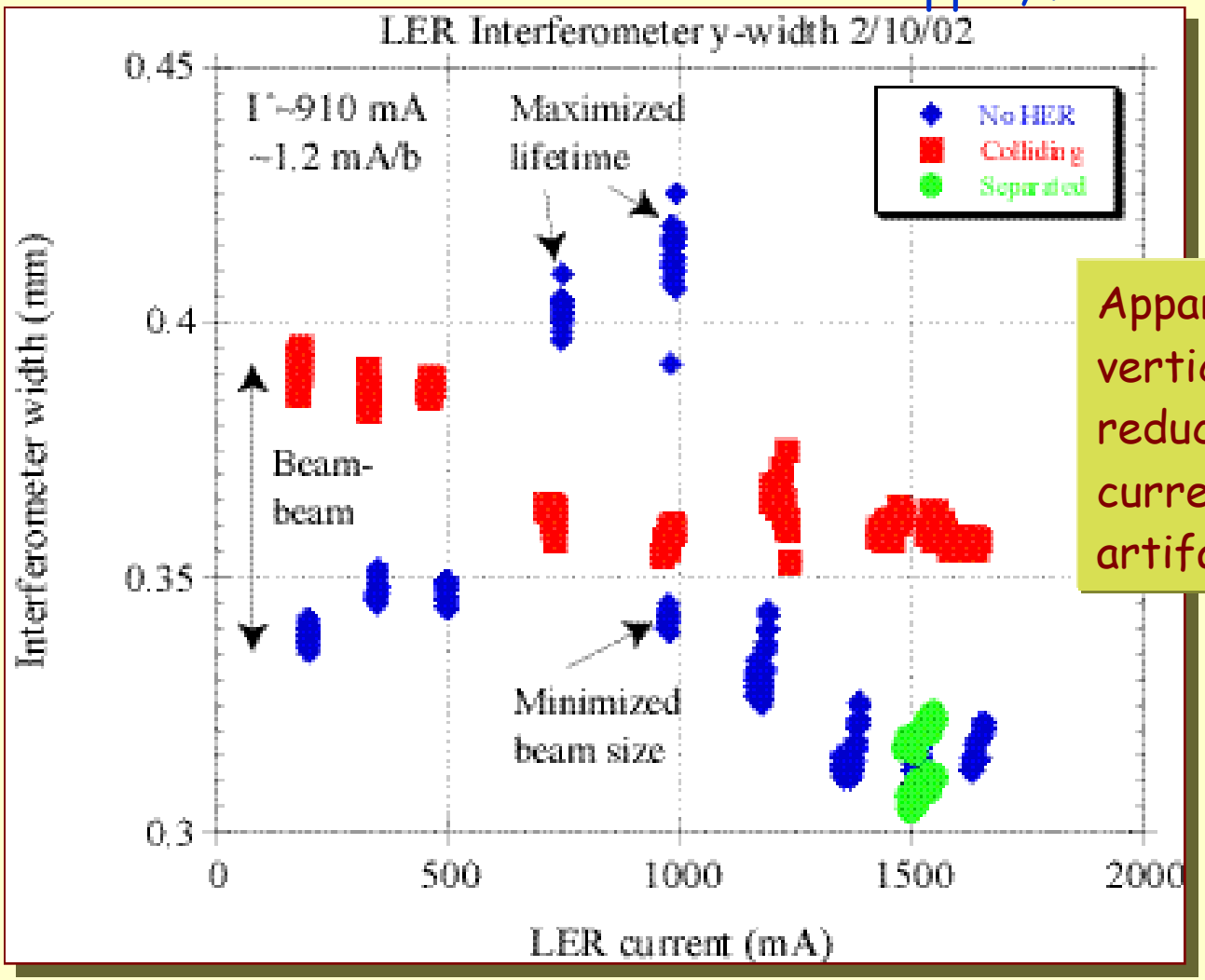
Holtzapple, Kozanecki



In 2002, with solenoids and gaps in bunch train (by-3, 6.3 ns), no more LER single-beam blowup

LER Beam Size (cont'd)

Holtzapple, Kozanecki



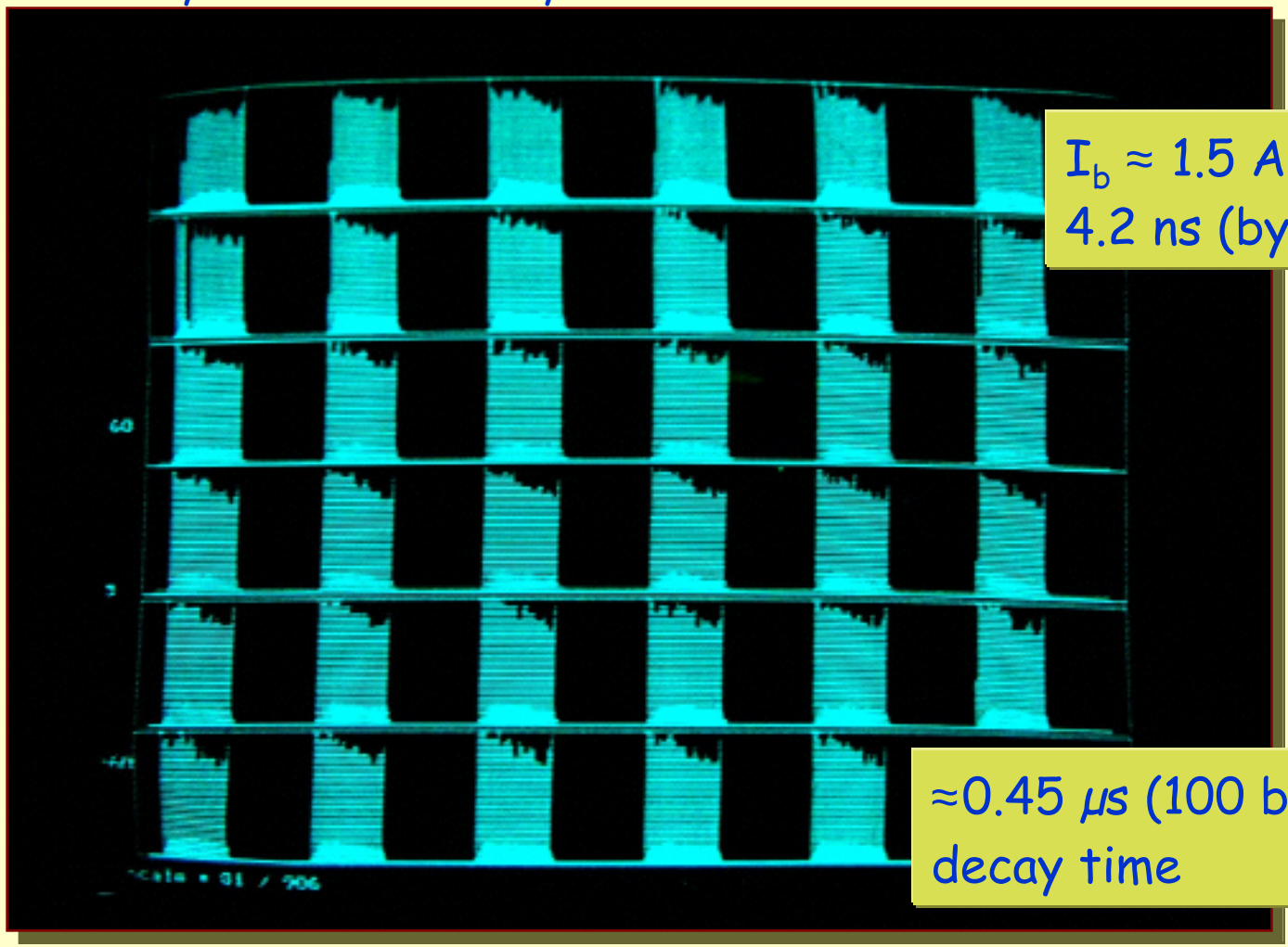
Apparent vertical size reduction with current may be artifact of SLM

Effect of different bunch spacing

- Most of 2003 running: 6.3 ns bunch spacing
  - Gradually, the mini gaps got filled in
  - Beam size does not appear to have grown!
- Recently bunch spacing reduced to 4.2 ns
  - Make room for more bunches
  - Re-introduced mini gaps
  - Initially luminosity droop reappeared…
  - But disappeared as we tuned up the machine.

4.2 ns Bunch Spacing in 2001

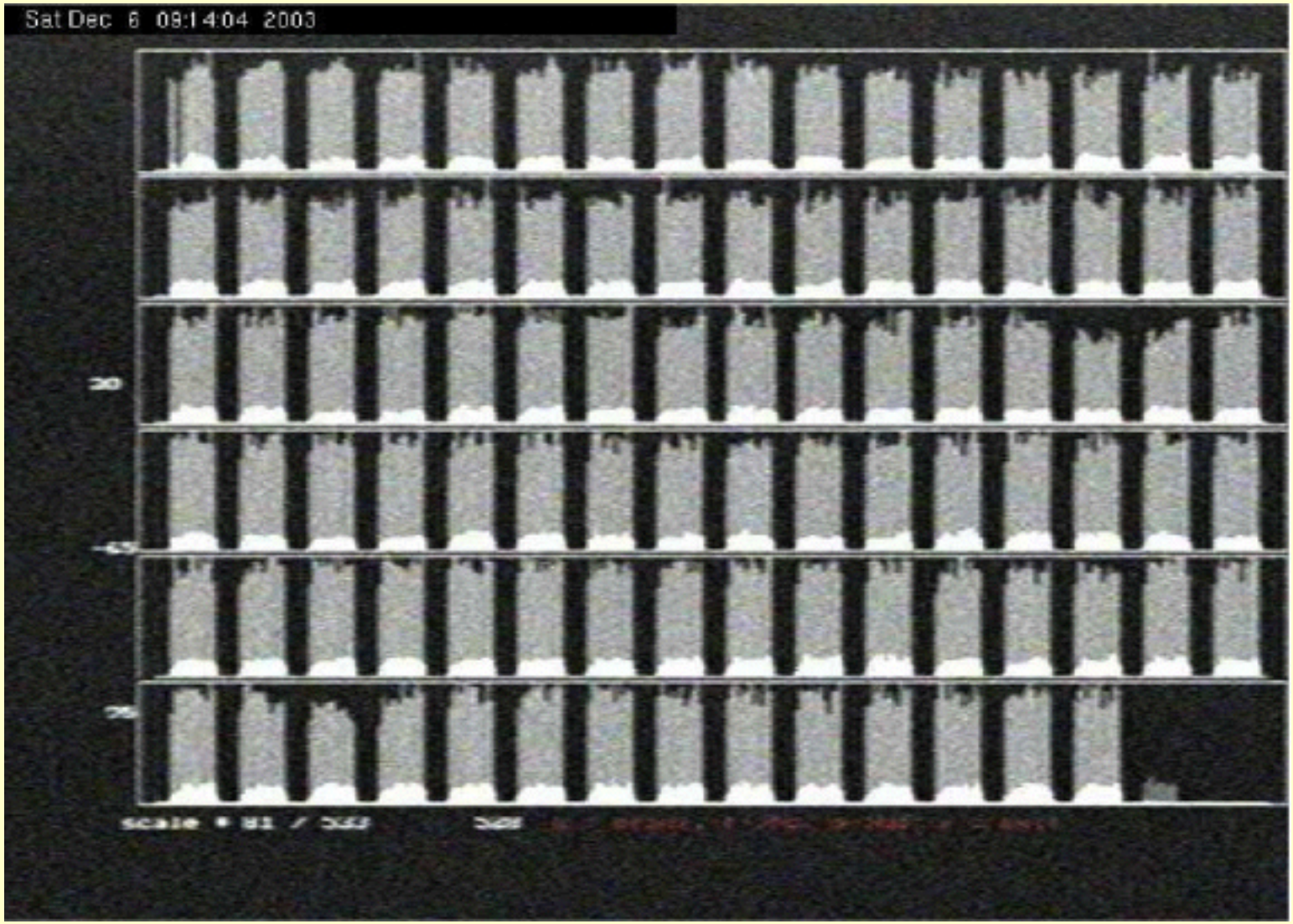
Bunch-by-bunch luminosity



$I_b \approx 1.5$ A
4.2 ns (by-2)

≈0.45 μs (100 bunches)
decay time

4.2 ns Bunch Spacing at Present



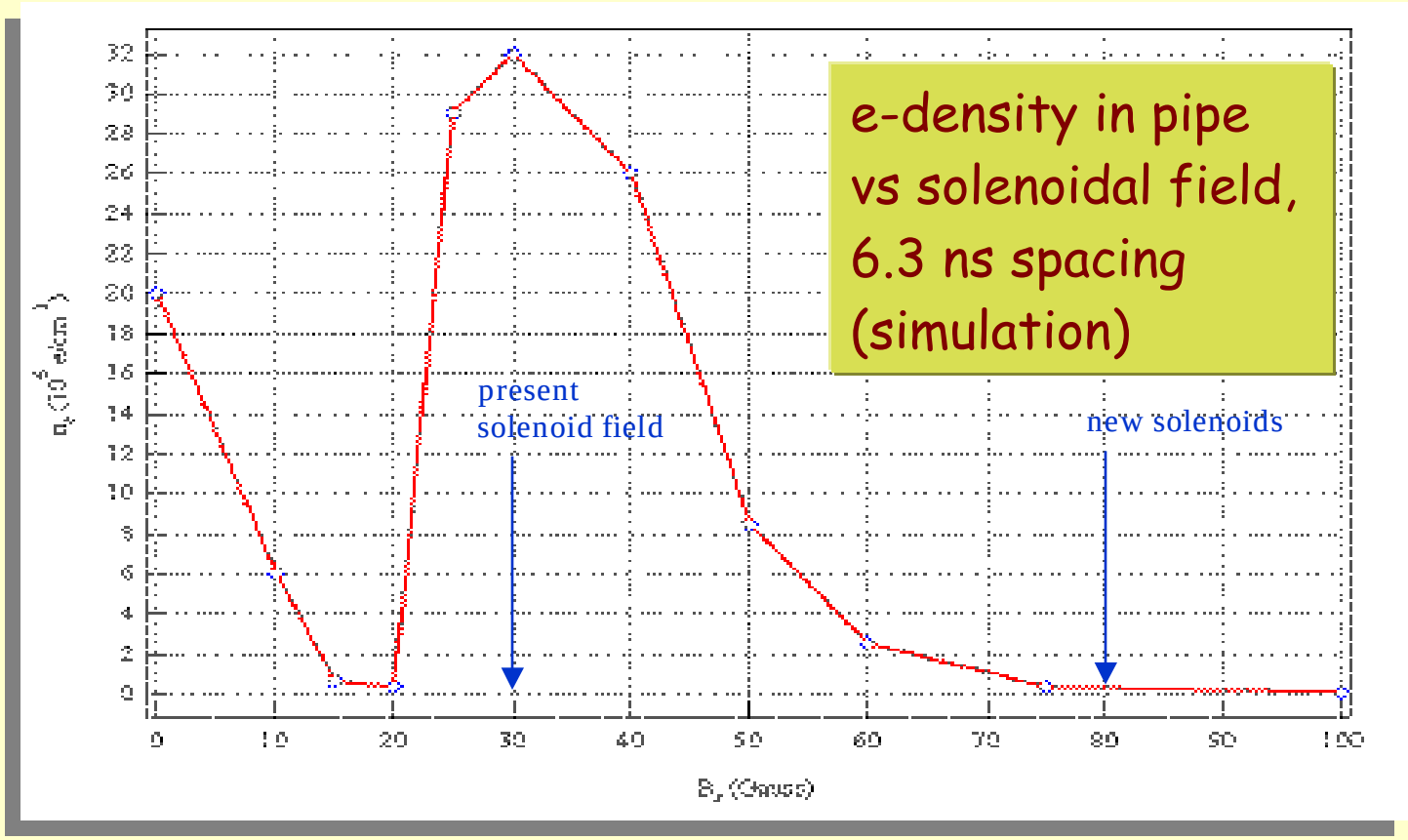
Issues for the Future

- PEP will go to higher beam currents
- Simulations predict reappearance of electron-cloud effects
  - Also predict "resonant" behavior with solenoid field strength, which are not seen in PEP.
- Photo electrons are not easily suppressed

- How important is "100%" field coverage ??
- What about electrons in the magnets ??

Electron Cloud *vs* Solenoid Field

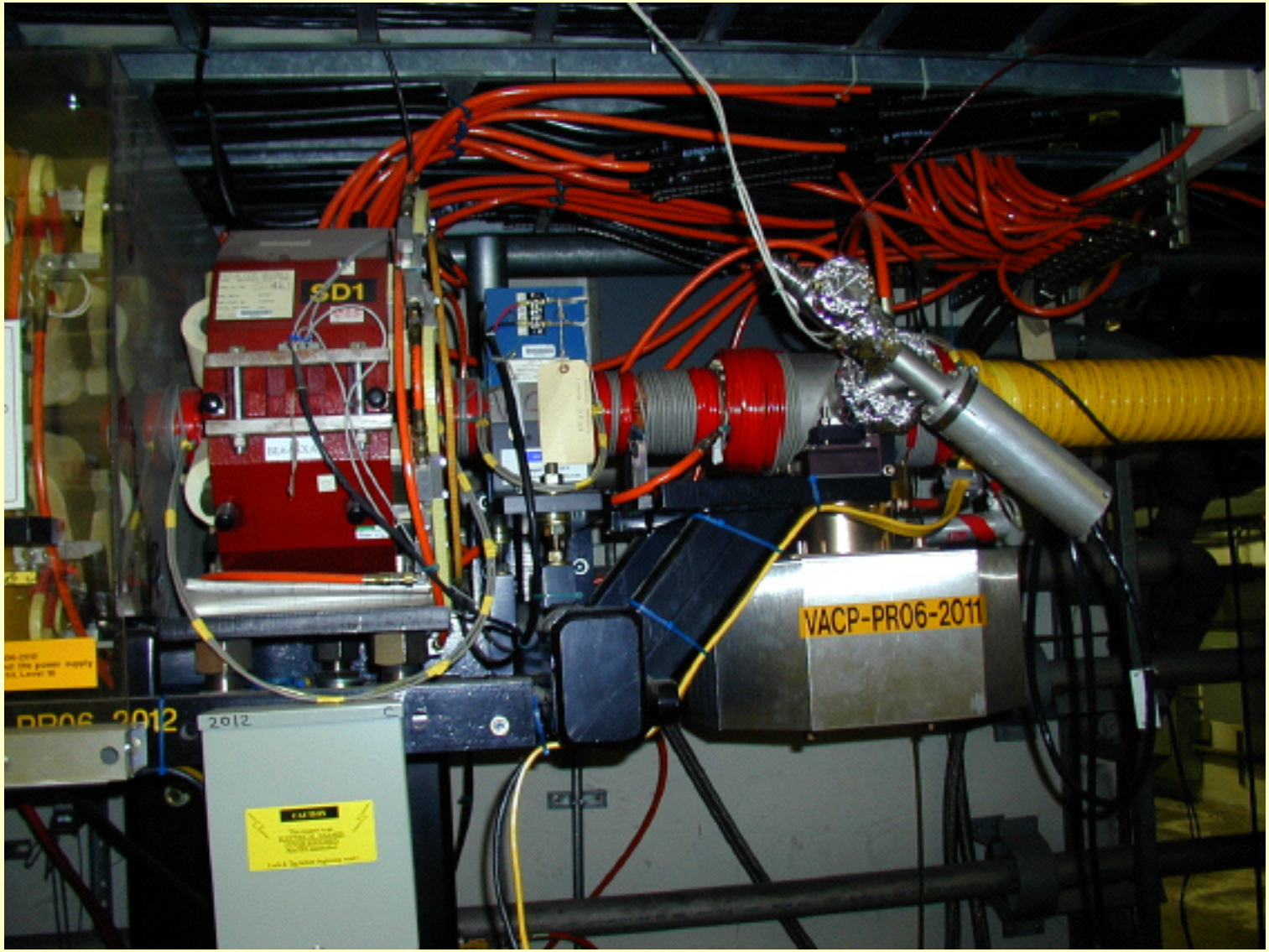
Cai, Pivi (PAC '03)



Measures taken or under consideration

- Increase field to ≈80 G in straight sect.
  - much more effective that increase of field in arcs
- "Fill in" some short spaces with solenoid
  - Hopefully can assess if effective or not
- Could try to install detector in skew quad
  - Simply not enough room in regular quad
  - Estimate by M. Pivi shows skew quad has sufficient gradient available
- Could TiN coat the drift chambers

Pumping Tee



Summary

- Multipacting in arcs & straights (solenoids off)
  - Pump currents and electron detector see it.
  - Gaps in 4.2ns spacing may reduce by don't cure it.
- Beam-pipe solenoids effective suppressing this
  - ≈ 20 G sufficient at highest present beam currents.
- Multipacting in single sections does not increase beam size
  - More than one arc or straight needed to affect lumi.
- Evidence for reduced impact on beam, now
  - No longer needed gaps in 6.3-ns fill
  - No luminosity droop in 4.2-ns spacing with gaps