Study of electron cloud build up in the MKDV1 in the SPS

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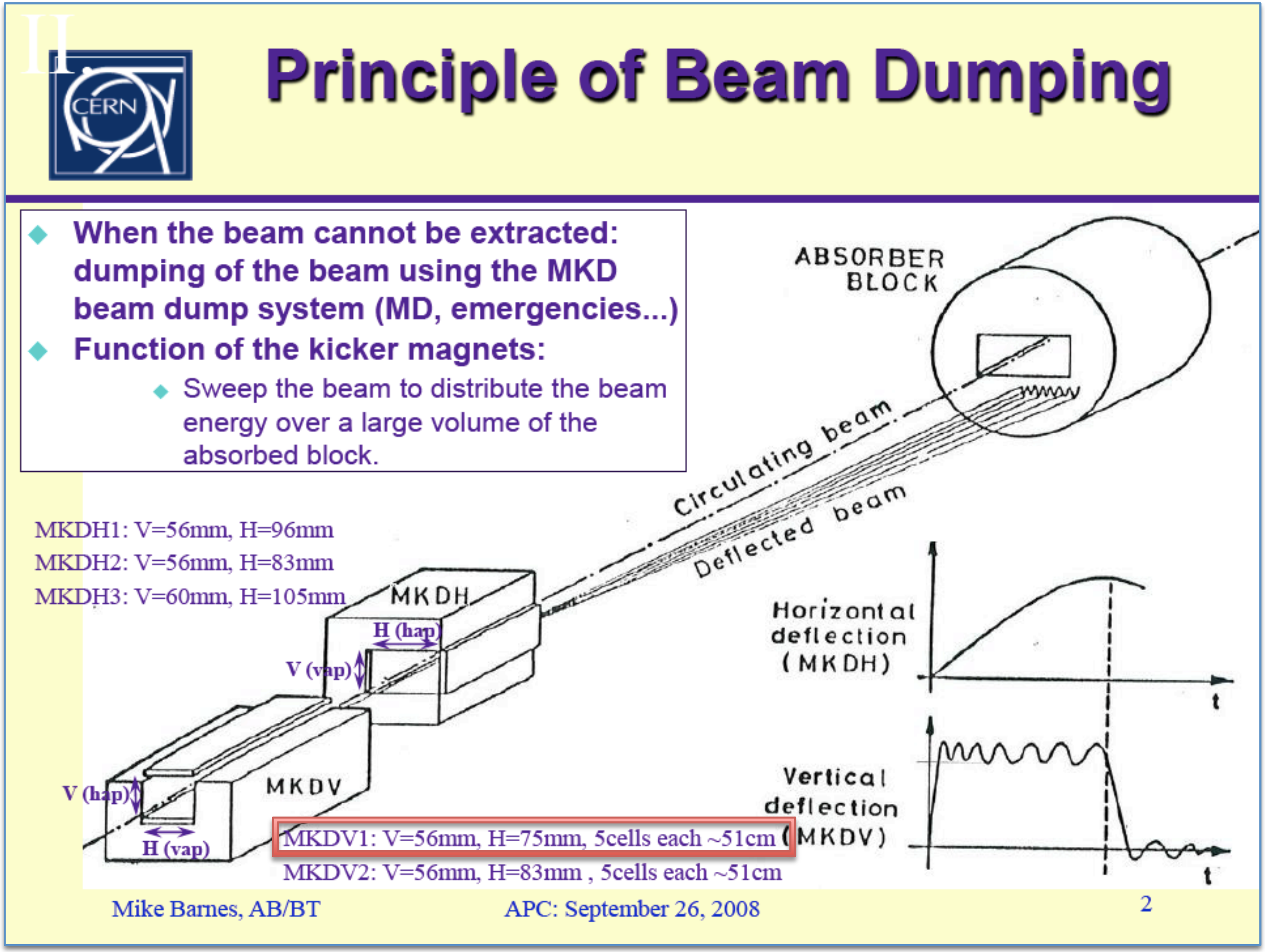
*thanks to G. Arduini, M. Barnes, K. Cornelis, E. Métral, G. Papotti, E. Shaposhnikova

- Background of this study
- Electron cloud simulations with ECLOUD:
  - Different bunch spacings
  - Some parameter scans
- Conclusions

For the LIS Meeting (17.11.2008)

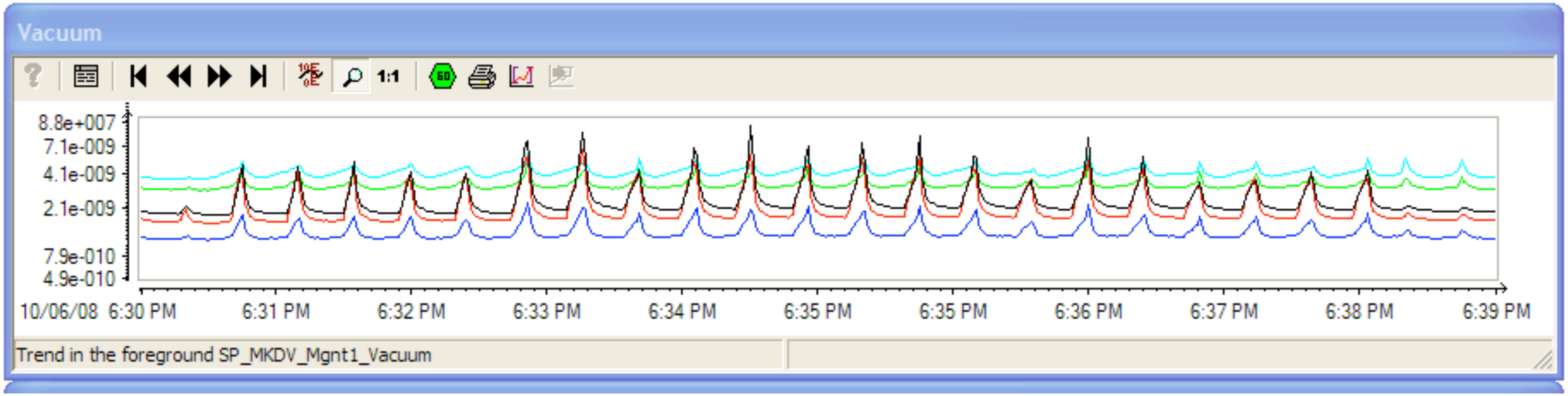
Inside the SPS the beam can be sent to an internal dump using the MKD kickers



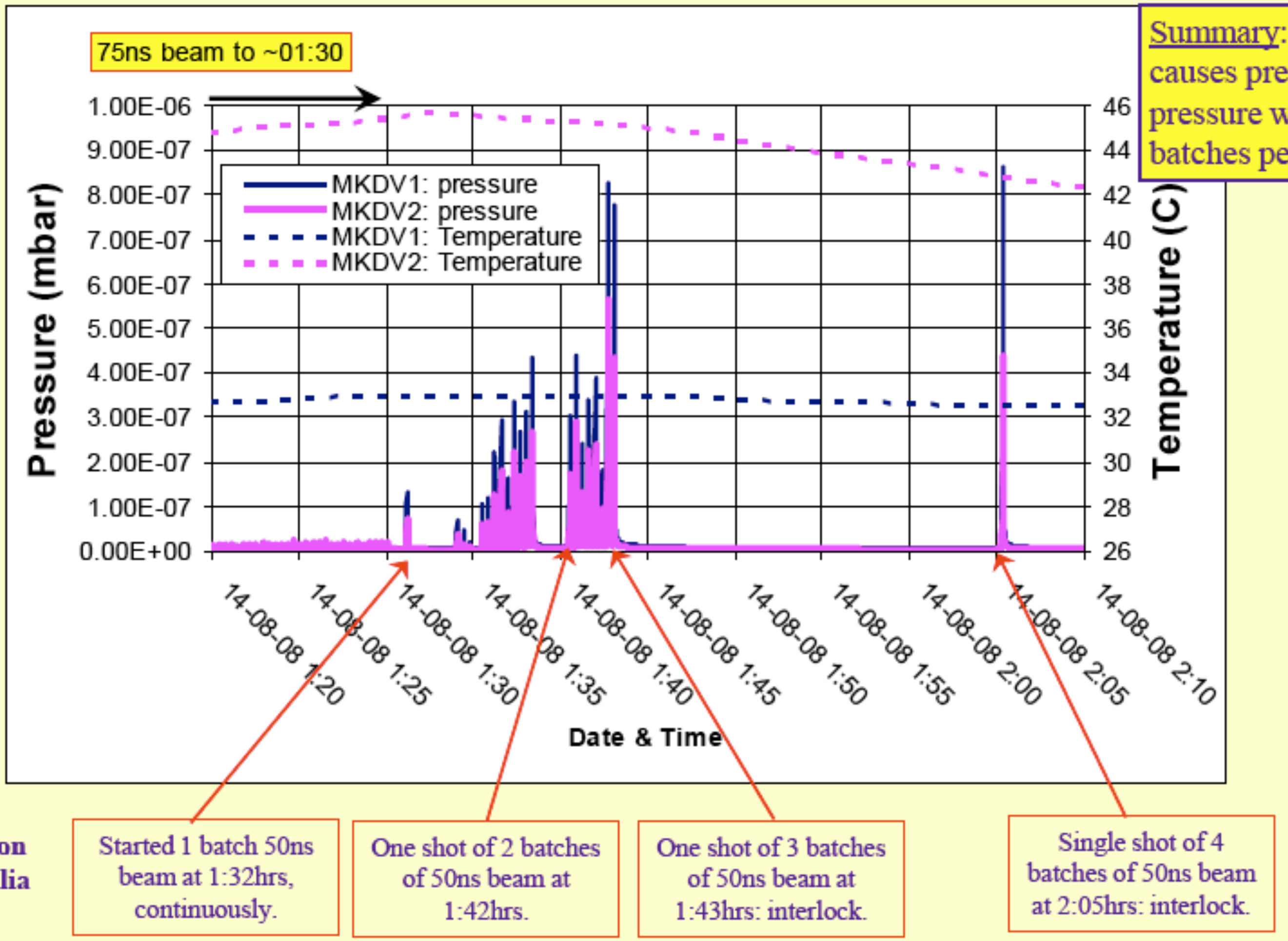
Outgassing and heating of the MKD kickers already limited the SPS performance in the 2007 run

⇒The MKDV1 was exchanged during the shut-down 2006-2007 and the installed one had unbaked ferrites.
⇒The 4 batches of the nominal LHC beam with 25ns spacing could not be accelerated to 450 GeV/c because of MKDV1 outgassing
⇒ Due to lack of time, the MKDV1 was not exchanged with a spare one treated at high temperature during the shut-down 2007-2008. Therefore in 2008 the SPS has been running with the same MKDV1 as in 2007.

2008 run => the outgassing problem appeared again, and surprisingly with 50ns bunch spacing and almost nominal intensity. Pressure rise seems to be concentrated in a sharp spike at the end of the LHC cycle.



MKDV Pressure on 14/08/2008, between 01:20hrs & 02:10hrs.



Summary: 50ns beam causes pressure rise; high pressure with 3 or 4 batches per shot.

Information from: Giulia Papotti:

With 25ns spaced LHC beam (nominal intensity, 4 batches), during the long MD in W41, outgassing of MKDV1 was observed and, on top of that, a deteriorating vacuum in MKDH3 from cycle to cycle.
However, the MKDV1 vacuum peak with the 50ns spaced 4-batch beam was higher.

Summary of 2008 observations

- Pressure in MKDV1 increases in high current operation
  - The worst pressure rise is observed with 50 ns beams
    - ✓ it mainly happens at top energy
  - runs with 25 ns beams exhibit a pressure rise all over the LHC cycle
    - ✓ peak values are lower than in the 50ns case
    - ✓ in some cases a peak is observed toward the end of the cycle
  - 75 ns beams cause low pressure rise
- The pressure in MKDH3 increases cycle by cycle in 25 ns operation and leads to vacuum interlock after a few cycles
- The temperature of MKDV2 increases when a 75 ns beam is circulating in the SPS
  - ✓ probably explained with the denser spectrum of a 75ns spaced beam with respect to 25 and 50ns spaced beams, held responsible for an unfavorable overlap with lines in the kicker impedance spectrum.

Could electron cloud build up in MKDV1 be responsible for the outgassing ?
Are the observations compatible with this ?

A simulation study with the **ECLOUD code** has been carried out, and we used the following sets of parameters

	β_x (m)	β_y (m)
MKDV1	23.6	94.51
MKDV2	28.55	81.1

Bunch length (1σ)

	FB (2 MV)	FB (3 MV)	FT
25 ns	0.92 ns	(0.6 ns)	0.35 ns
50 ns	0.92 ns	0.6 ns	0.31 ns
75 ns	0.9 ns	(0.6 ns)	0.31 ns

Giulia Papotti

MKDV1

	25, 75 ns	50 ns
σ_x @26 GeV/c	1.6 mm	0.9 mm
σ_y @26 GeV/c	3.2 mm	1.8 mm
σ_x @450 GeV/c	0.38 mm	0.22 mm
σ_y @450 GeV/c	0.77 mm	0.44 mm

* The beam sizes are smaller at 50ns than at 25 and 75ns because the 50ns beam is produced with lower transverse emittances at the PSB (~1 μm instead of 2.7 μm)

Simulations have been done

⇒ Using SPS parameters at **injection** and at **top energy** (different bunch sizes, see values in the previous slide)

⇒ For **25, 50 and 75ns bunch spacings** (4 batches with 72, 36, 24 bunches)

⇒ With several δ_{max} to determine the threshold value for the onset of the e-cloud

⇒In **field-free space** or with **horizontal magnetic field**

- ✓ low-moderate (30 Gauss)
- ✓ possible cyclotron resonance for the 50ns case (7.15 Gauss)
- ✓ realistic value for the remnant kicker field, as provided by M. Barnes and V. Senaj (1 Gauss)

⇒ Scanning a few values of E_{max} to try to explore whether there is a combination of parameters which could cause more electron cloud with 50ns spacing than with 25ns spacing (at least at top energy)

⇒ Bunches always with **nominal intensity**

Unfortunately the number of parameters (beam sizes, bunch spacing, secondary emission model, magnetic field, bunch intensity) and the non-trivial dependence of the build-up on each of them (no simple scaling laws) could require more attempts….

Build up threshold for nominal beam at 25ns spacing

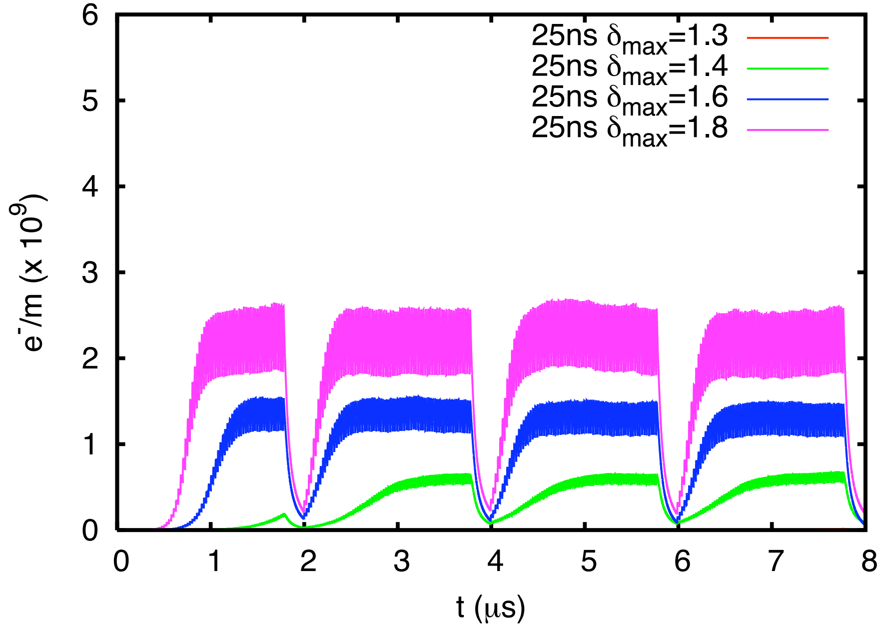
⇒ Simulations done in field-free space

⇒ At injection the threshold value for the maximum SEY lies between 1.3 and 1.4

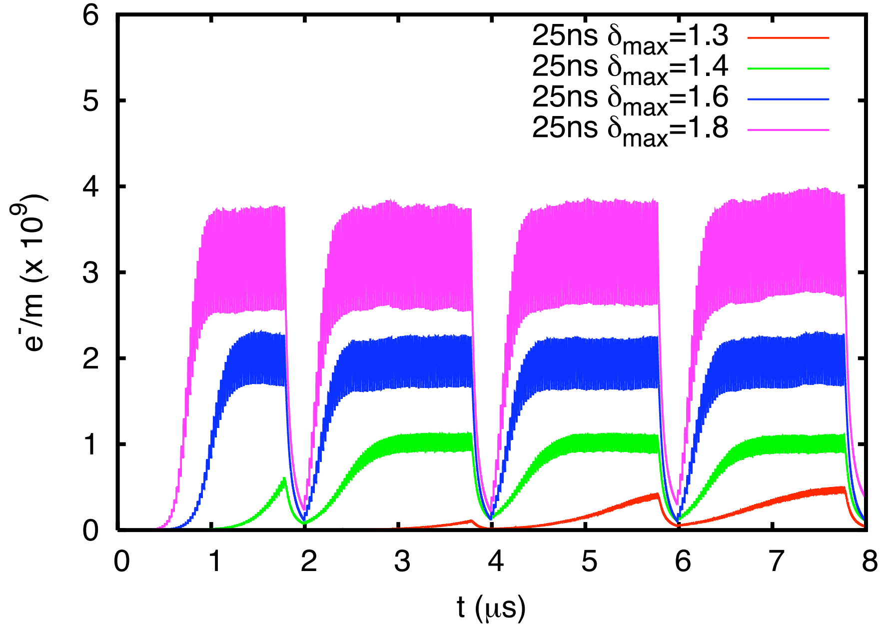
⇒ At top energy there is already a little build-up for a maximum SEY of 1.3

⇒ Saturation values at top energy are about a factor 1.5 larger than at injection

Injection



Top energy



Build up threshold for nominal beam at 50ns spacing

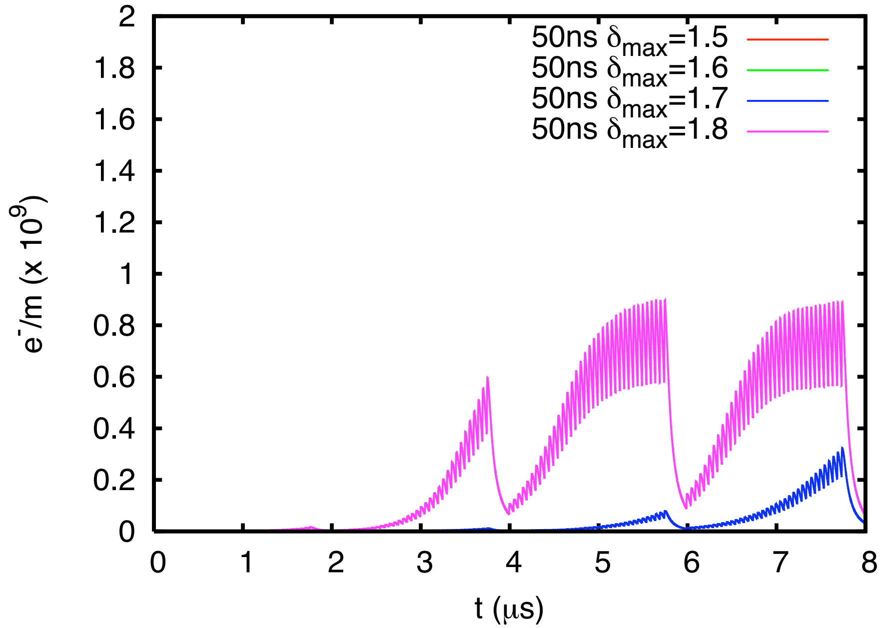
⇒ Simulations done in field-free space

⇒ At injection the threshold value for the maximum SEY lies between 1.6 and 1.7

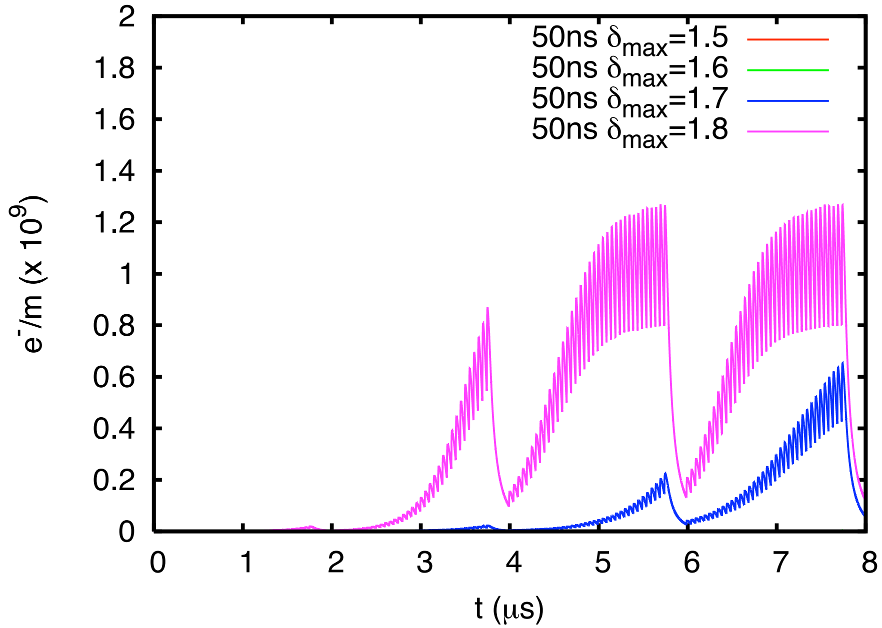
⇒ At top energy the threshold does not change

⇒ The saturation value at top energy for SEY=1.8 is about 1.5 larger at top energy

Injection



Top energy

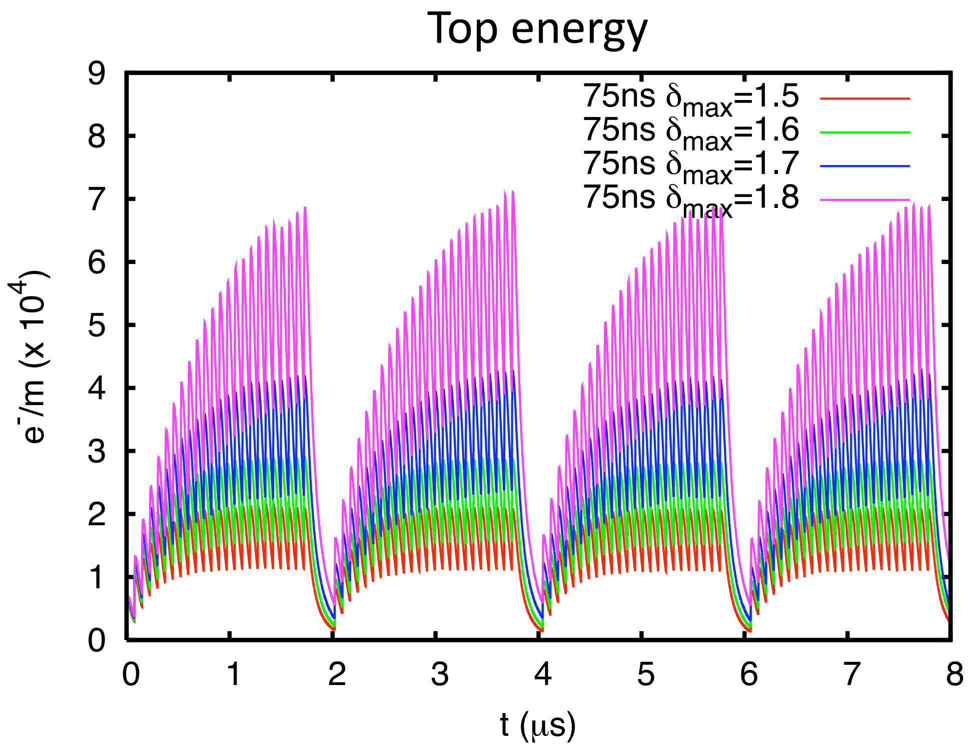


Build up threshold for nominal beam at 75ns spacing

⇒ Simulations done in field-free space

⇒ No electron cloud build up observed at top energy for SEY up to 1.8

⇒ The threshold for electron cloud build up with 75ns spaced LHC beams is higher than 1.8 in a field-free region



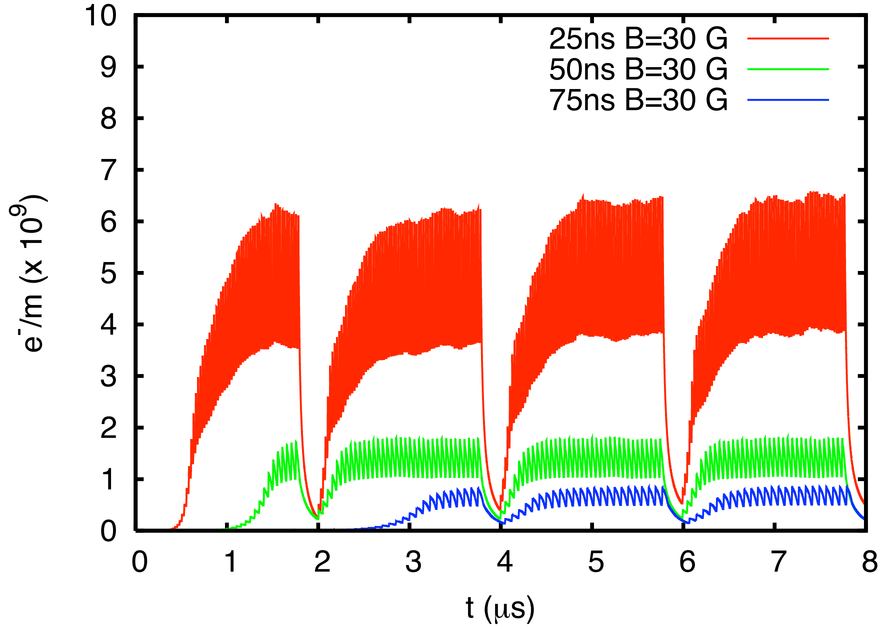
Build up in a region with a horizontal constant magnetic field

⇒ B= 30 G

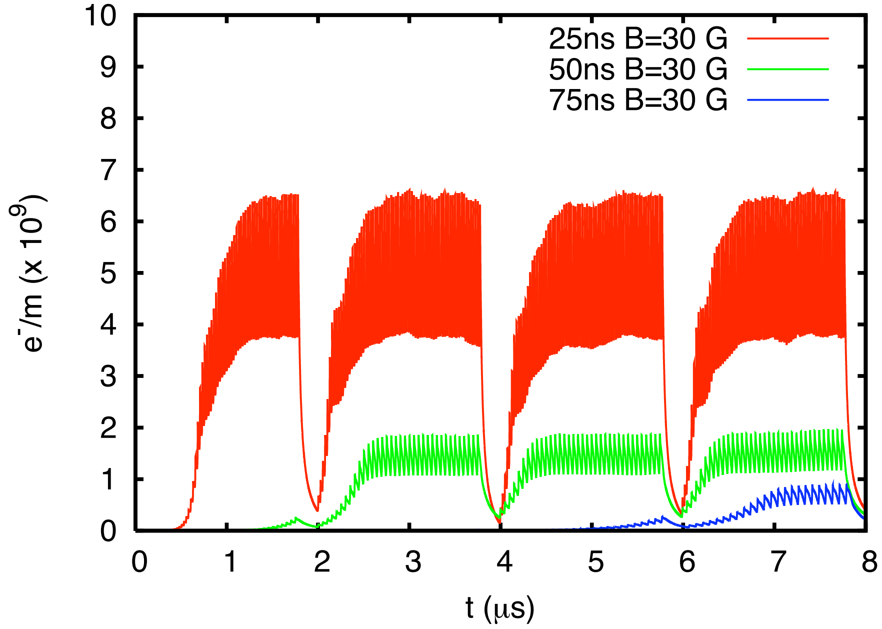
⇒ There is significant electron cloud build up for all three spacings, but higher values have to be expected for 25ns

⇒ There is no big difference between injection and top energy, except that the build up is perhaps a little slower at top energy

Injection



Top energy



Build up in a region with a horizontal constant magnetic field

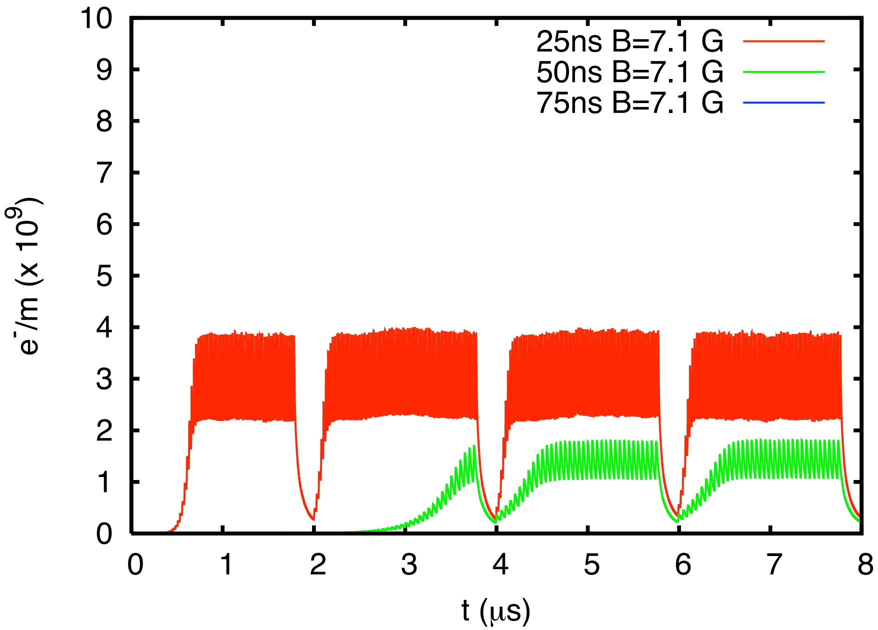
$$\Rightarrow \quad B = n\frac{2\pi m_e}{q\tau_b} \quad (\tau_b \text{ bunch spacing})$$

$$\Rightarrow \quad B << 2\pi\frac{m_e c}{q l_b} \quad (l_b \text{ bunch length})$$

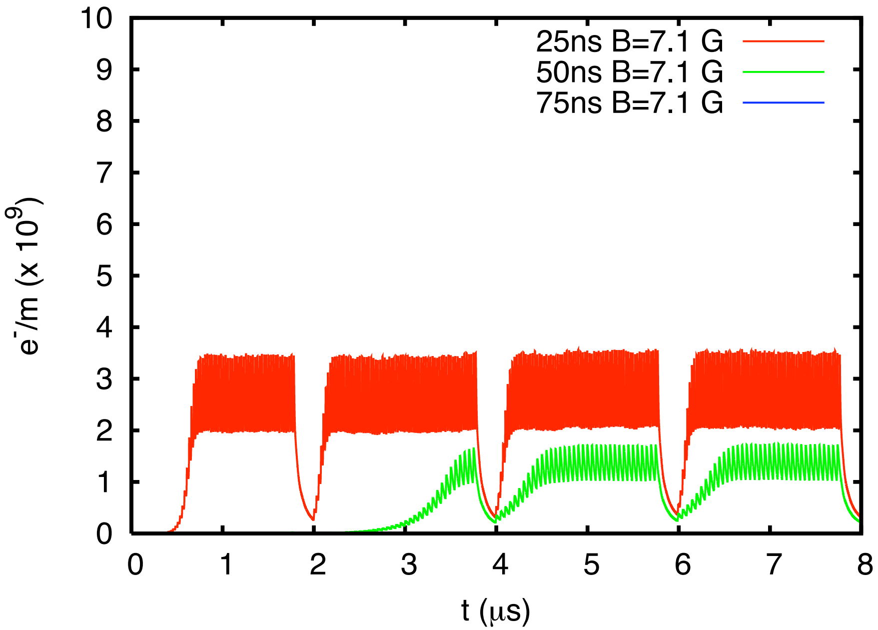
=> B= 7.15 G with n=1 and τ_b=50ns

⇒ No e-cloud with 75ns, a factor 2 less than before with 25ns, same as before with 50ns

Injection



Top energy

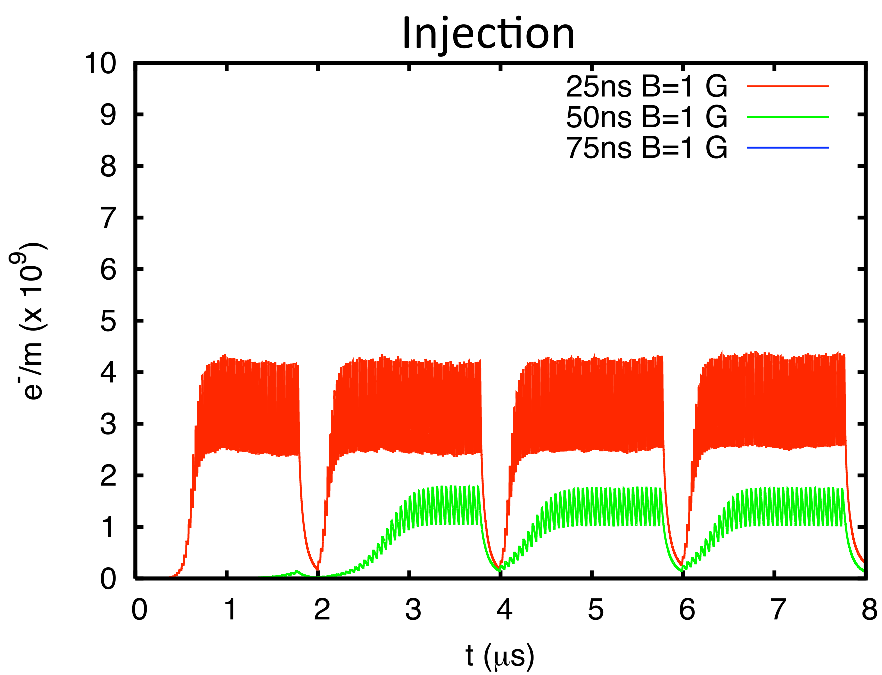


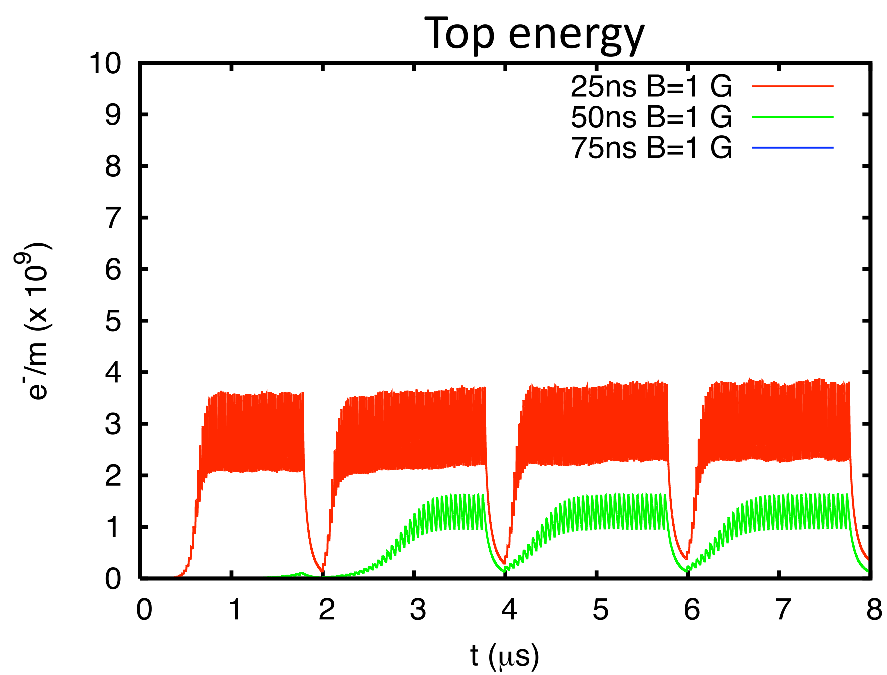
Build up in a region with a horizontal constant magnetic field

⇒ B=1 G

⇒ Realistic value for the remnant magnetic field in a MKDV kicker (M. Barnes)

⇒ Similar dynamics as with B=7.1 G, but still about a factor 3 difference between the electron cloud expected with 25ns LHC beams and with 50ns LHC beams



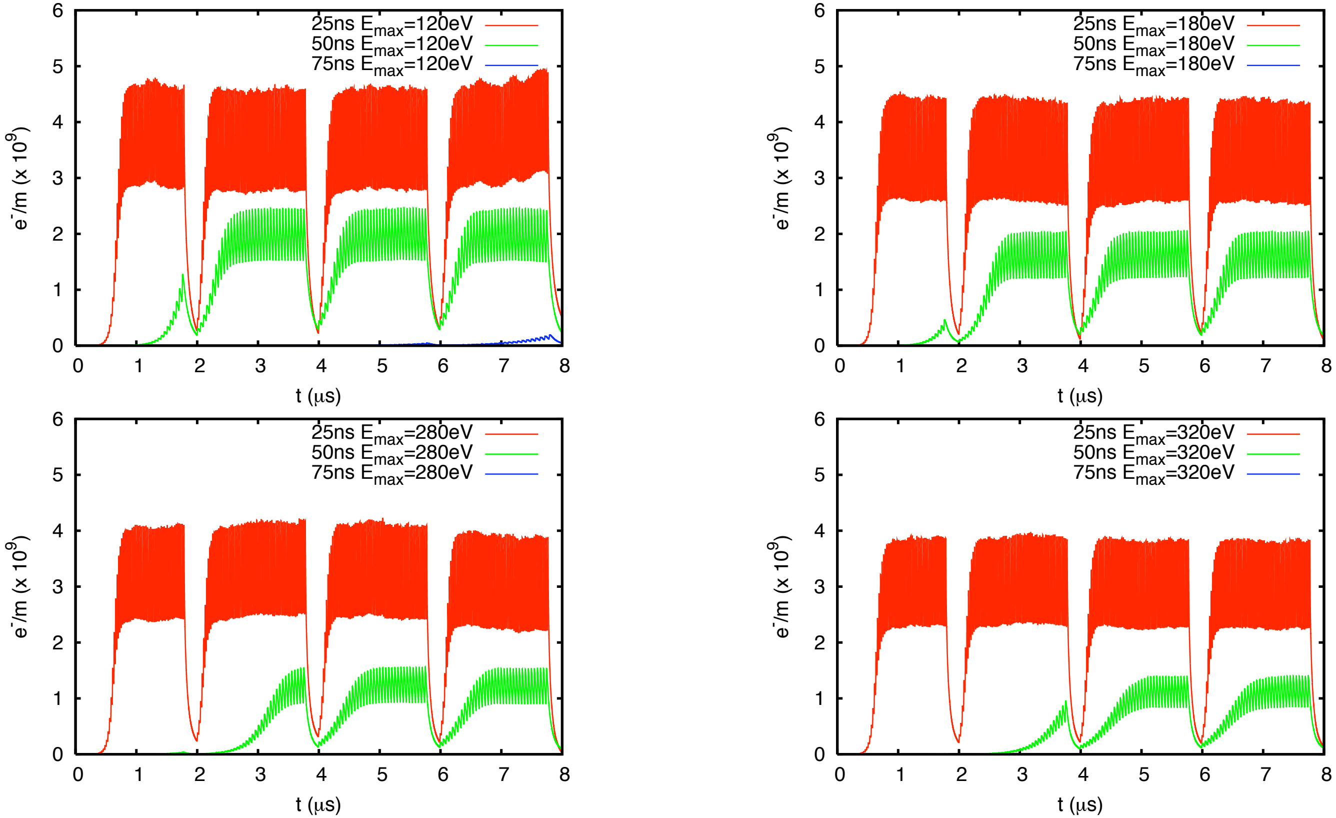


Build up in a region with B=1 G and for different E_{max} in the SEY model

⇒ The position of the peak in the SEY model some times can change the features of electron cloud build up for bunches of different lengths and differently spaced.

⇒ We have scanned E_{max} from 120 eV to 320 eV (all previous simulations done with E_{max}= 230 eV)

⇒ The 25ns results do not seem to be much affected by the position of the maximum in the SEY curve. E-cloud with 50ns is enhanced by lower E_{max}



Conclusions

⇒ If the maximum SEY is high enough (≥1.8) we can have significant electron cloud build up inside the MKDV1 both with 25 and 50 ns spaced LHC beams circulating in the SPS.

⇒ Simulations in a field-free region show a saturation value of the electron cloud density that is a factor 1.5 higher at top energy than at injection.

⇒ Differences between the electron cloud build up at injection and at top energy are almost negligible when the remnant magnetic field in the kicker is taken into account.

⇒ Neither in field-free region nor with a low magnetic field we find a case in which the electron cloud created by a 50ns spaced LHC beam has a higher density than the one created by a 25ns spaced LHC beam

⇒ E_{max} scan also shows that the e-cloud build-up is not much affected by this parameter

⇒ Maybe try simulations with lower currents (e.g. at 50ns we always ran with 80% of the nominal intensity) and higher maximum SEY ?

⇒ Maybe increase the probability of reflection of electrons at low energy (presently 0.7), which is more likely to affect the e-cloud evolution with larger bunch spacing ?

⇒ Other ideas ?