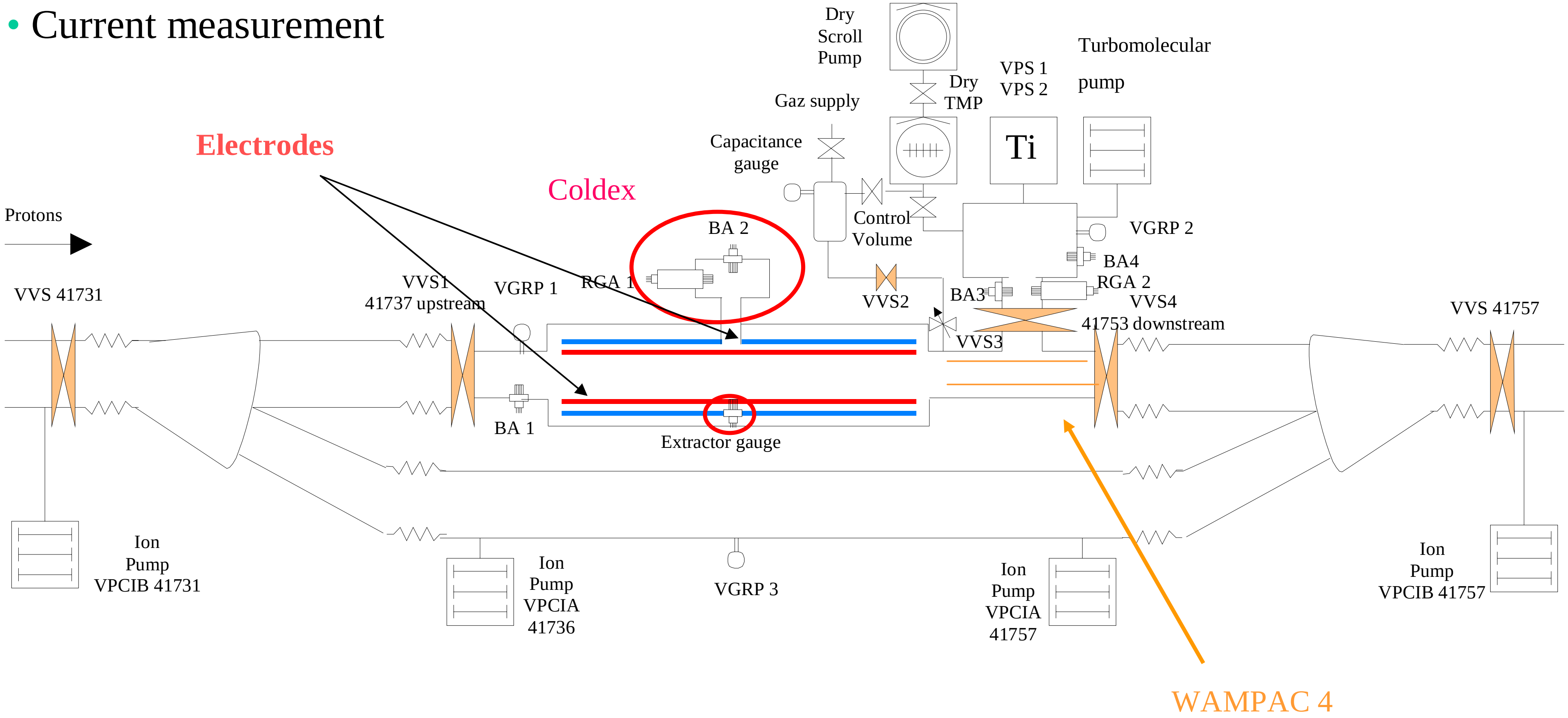
Latest Results from COLDEX

V. Baglin, B. Jenninger

CERN AT-VAC, Geneva

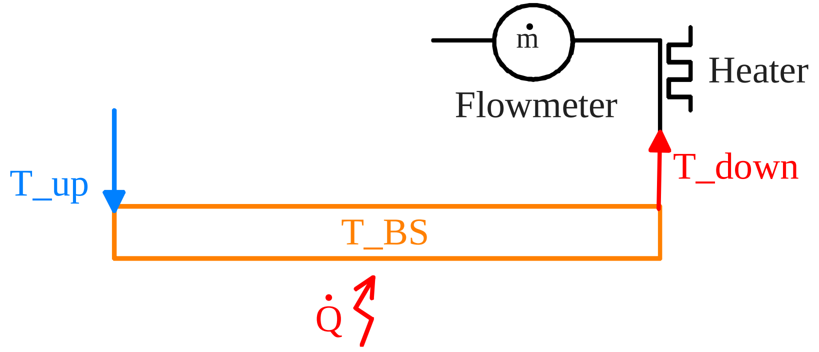
1. Experimental set-up

- Field free region (SPS Long straight section 4), closed geometry
- OFE Cu, 2.2 m long, circular, D= 67 mm (cleaned following LHC standard)
- Cryogenic temperature, 1 % slots (2 x 7.5 mm), BS ~ 5 to 100 K, CB ~ 3 to 5 K
- Pressure measurement, gas composition
- Heat load measurement
- Current measurement



- Electron shields behind slots (L = 17.85 cm) protect cold bore
- One electron collector behind the slots of the beam screen
- Central electrode in the chimney
- Cold warm transition with RF fingers. Stainless steel Cu coated, thermally anchored
- Flow method, He at 1 bar :

$$\dot{Q} = \dot{m}\left[h_{He}(T\_down) - h_{He}(T\_up)\right]$$



- Calibrated thermometer, Calibrated flowmeter
- Background : ~ 0.9 W/m
- In situ heat load calibration, ~ 100 mW/m is measurable

- WAMPAC 4, TiZrV coated onto Cu, ID 67 :
  at the downstream position problem during activation up to 400 degrees !!!
  but repaired for MD of September 2005

2. Pressure Increase

- With 2 batches , the total pressure starts ~ 2 10^{-8} Torr and reach ~ 3 10^{-9} Torr after 5 days

- The pressure remains constant throughout the year

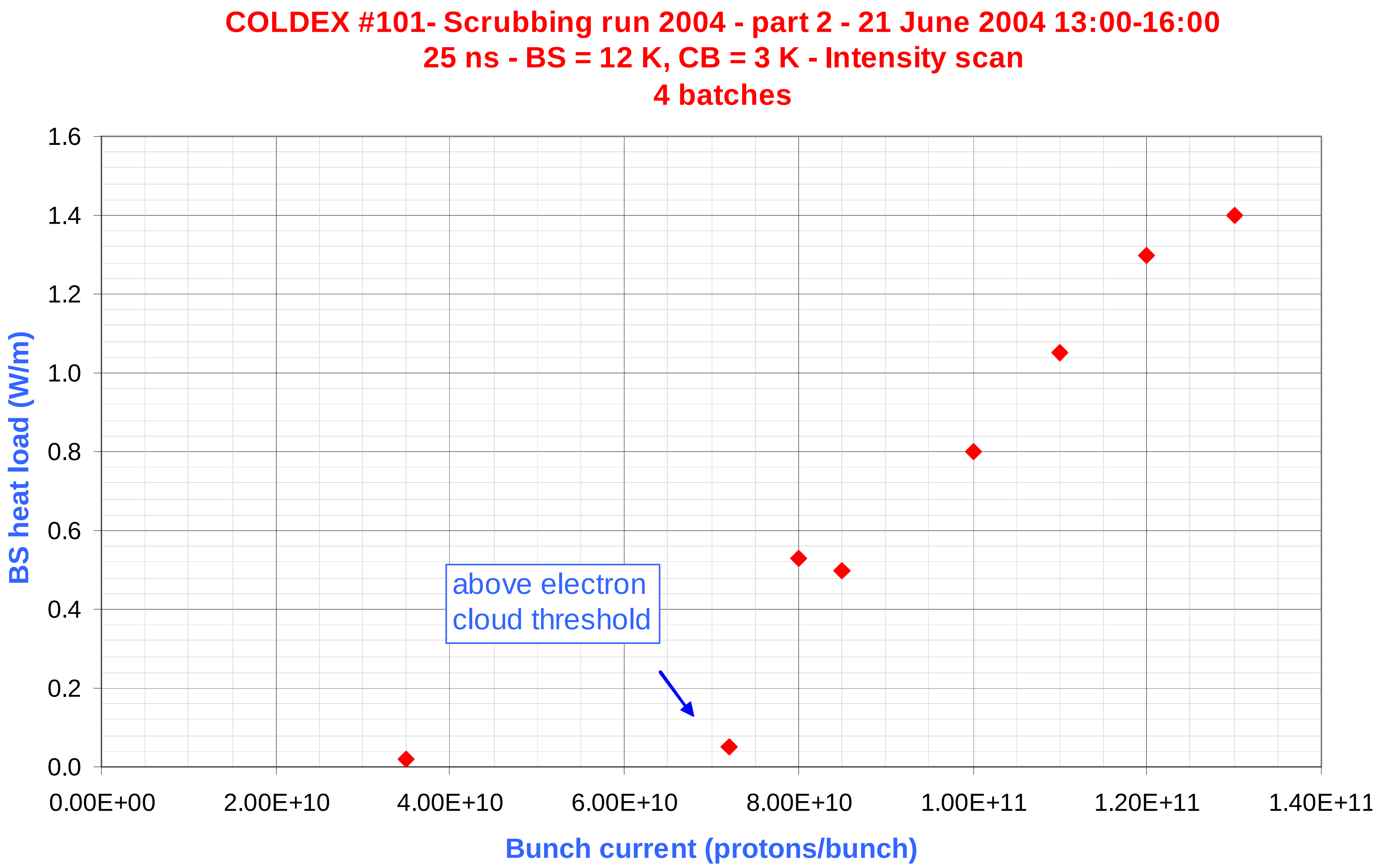
- The residual gas composition :

    - H_2 = 2 10^{-9} Torr
    - CH_4 = 3 10^{-10} Torr
    - H_2O = 1 10^{-10} Torr
    - CO = 1 10^{-9} Torr
    - CO_2 = 8 10^{-11} Torr

3. Heat load

2nd week of scrubbing run : Intensity scan

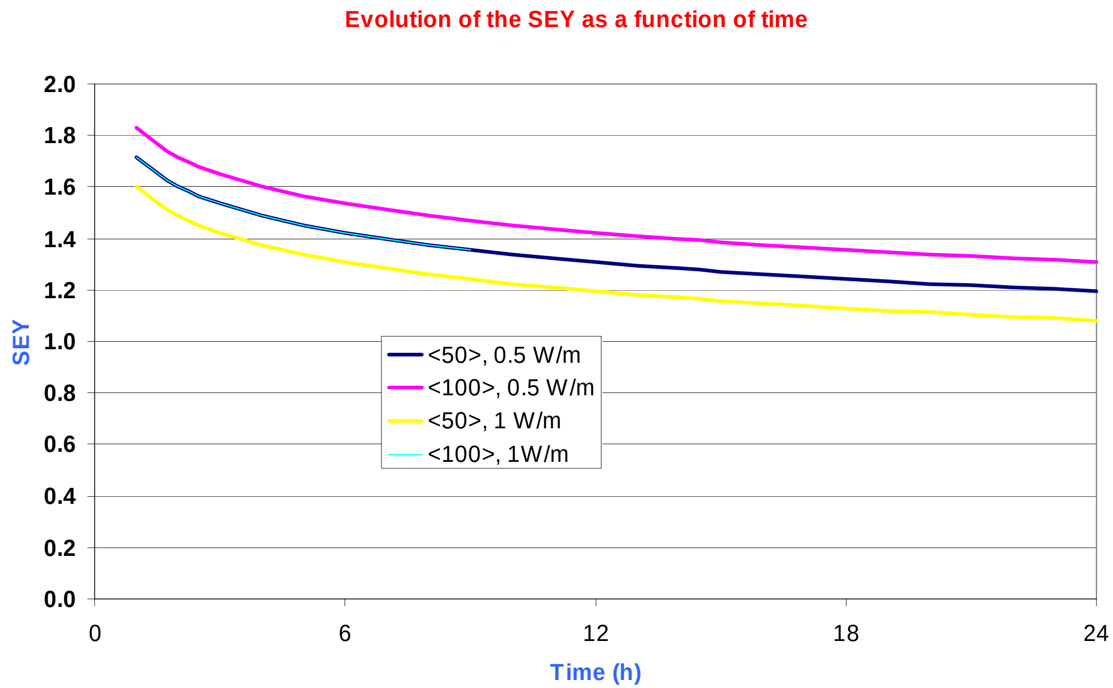
Threshold at 7 10^{10} p/bunch



Electron dose

- First estimation : electron cloud with a <u>single</u> energy 50 or 100 eV

- Estimation of the electron dose and the SEY in COLDEX

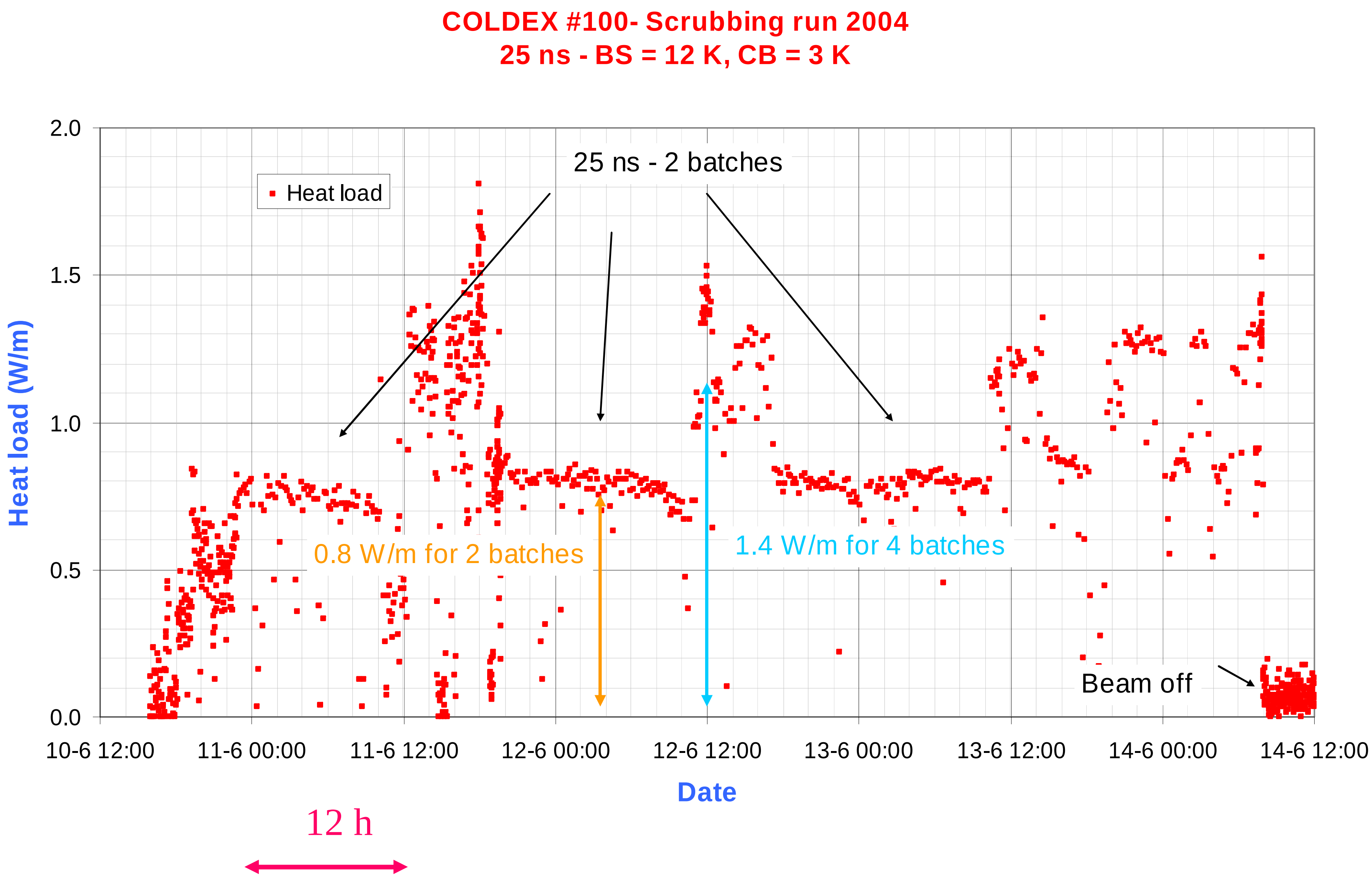


- After 12h with 0.5 or 1 W/m the SEY should be in the range 1.2 -1.4

- According to ECLOUD, the heat load measured in COLDEX is reached in ~ 10 h

Raw data of Heat load at 25 ns, 1st week of scrubbing run

Heat load onto the BS is 0.8 W/m when 2 batches with 25 ns circulated and 1.4 W/m for 4 batches (beam current decreased)



- The heat load measured onto the BS is normalised to 4 batches (0.22 A)

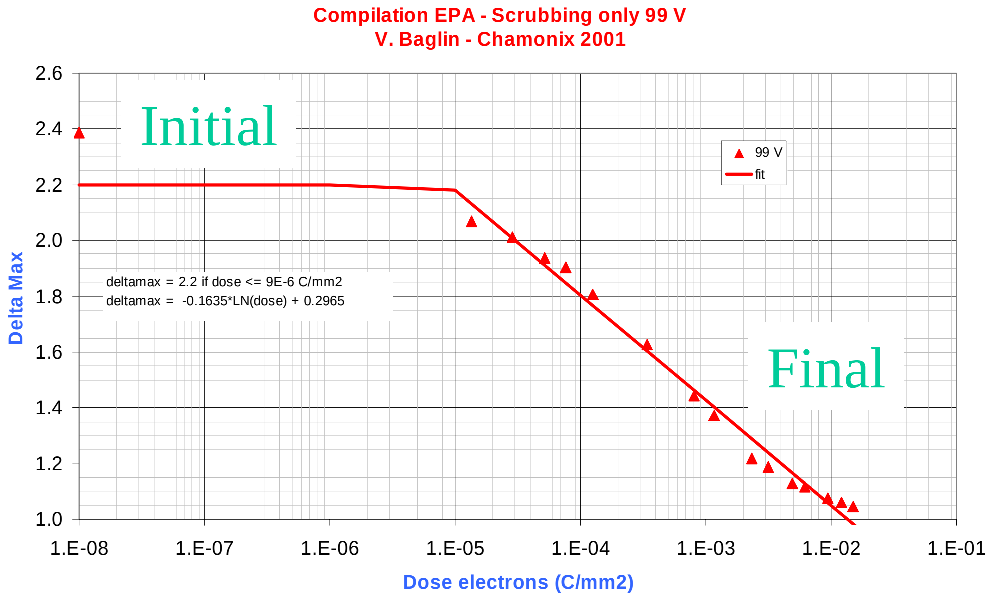
- The heat load is compared to the heat load prediction of the ECLOUD code version march 2004 using the secondary electron yield (SEY) as an input

- The mean energy of the cloud and the fraction are given by (simulation for WAMPAC 3, FZ 31.3.04):

δ	2.2	2.1	2	1.9	1.8	1.7	1.6	1.5	1.4	1.3	1.2	1.1	1.0
<E>	40	40	40	45	50	57.5	65	77	90	97.5	115	125	140
F (%)	25	25	25	28	30	35	40	45	50	60	70		

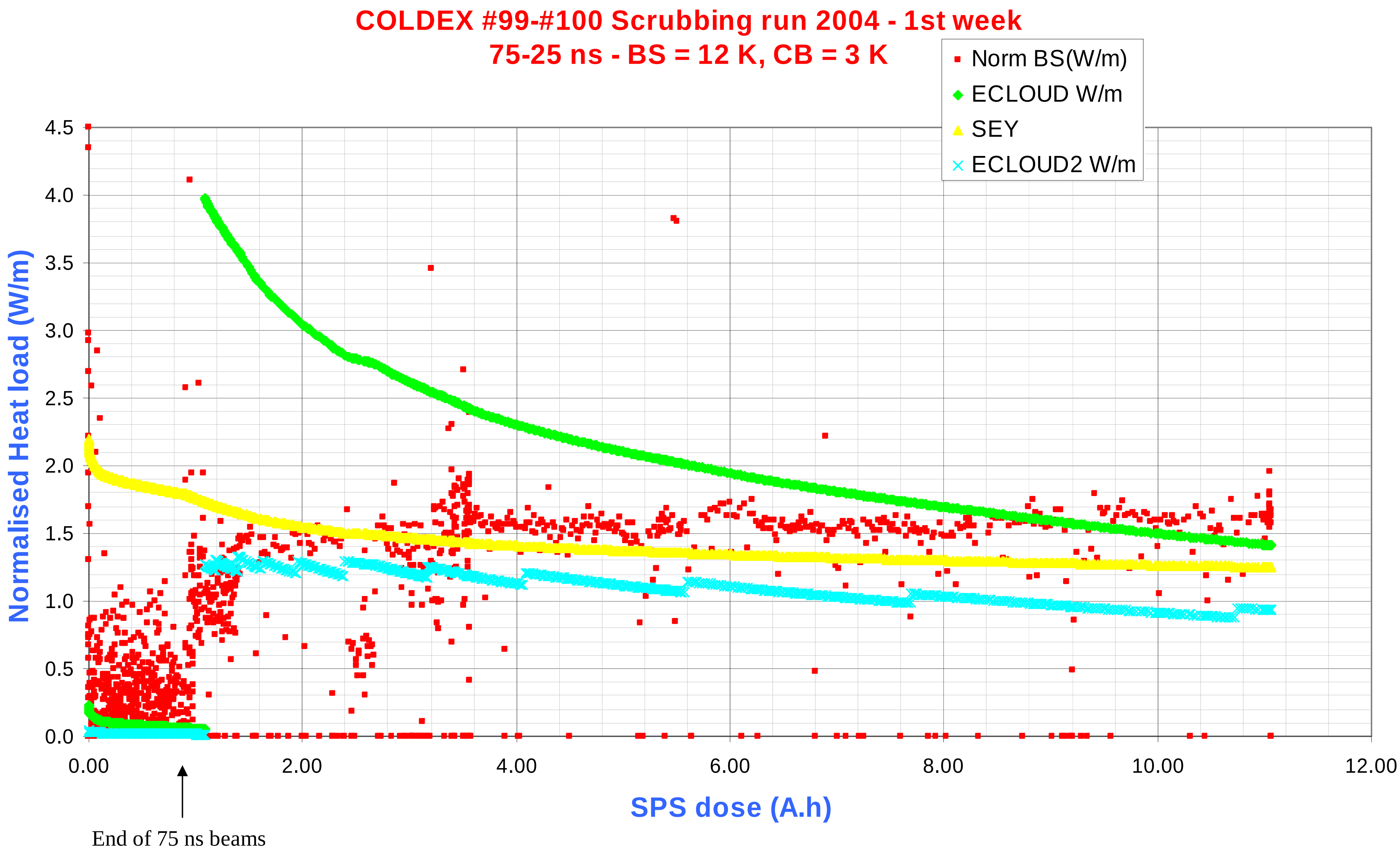
- The electron dose is computed, by successive iterations, from the measured dissipated heat load onto the BS and the estimated mean energy of the cloud given by ECLOUD and the fraction of electron above 30 eV energy given by ECLOUD

- From the electron dose is computed a SEY following EPA measurements (V. Baglin *et al.* Chamonix 2001)



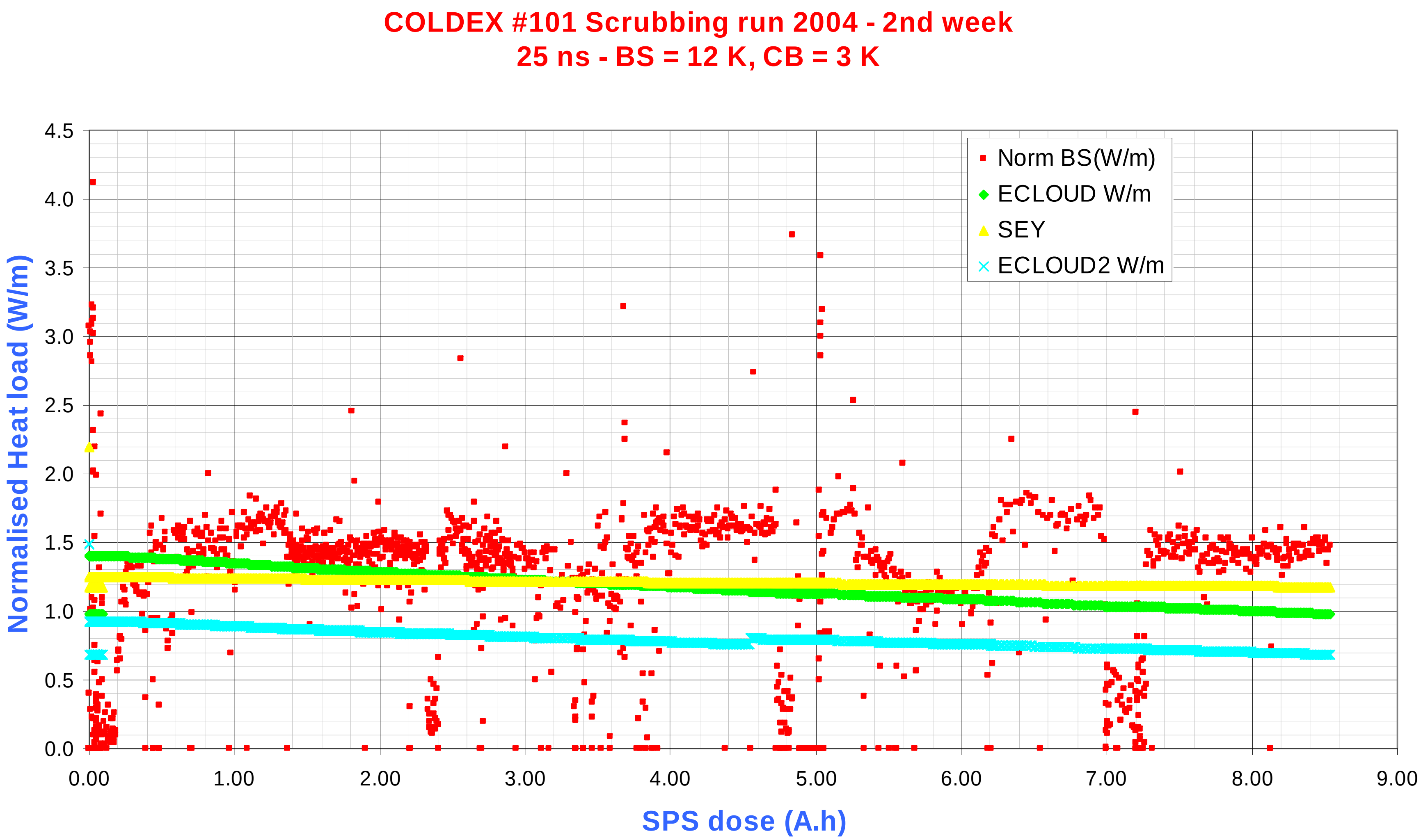
1st week of scrubbing run with 75 ns and 25 ns

Normalised (4 batches) heat load and predicted SEY and heat load by ECLOUD



2nd week of scrubbing run with 25 ns

Normalised (4 batches) heat load and predicted SEY and heat load by ECLOUD



• At 5 A.h (23/6/04, 12h), a warm up to 220 K of the BS followed by a cool down did not change the level of the heat load

MD : Comparison with saturated NEG

- WAMPAC 4 : NEG activated since 12 days,
  COLDEX is held at room temperature
  So it is saturated, expected SEY ~ 1.3

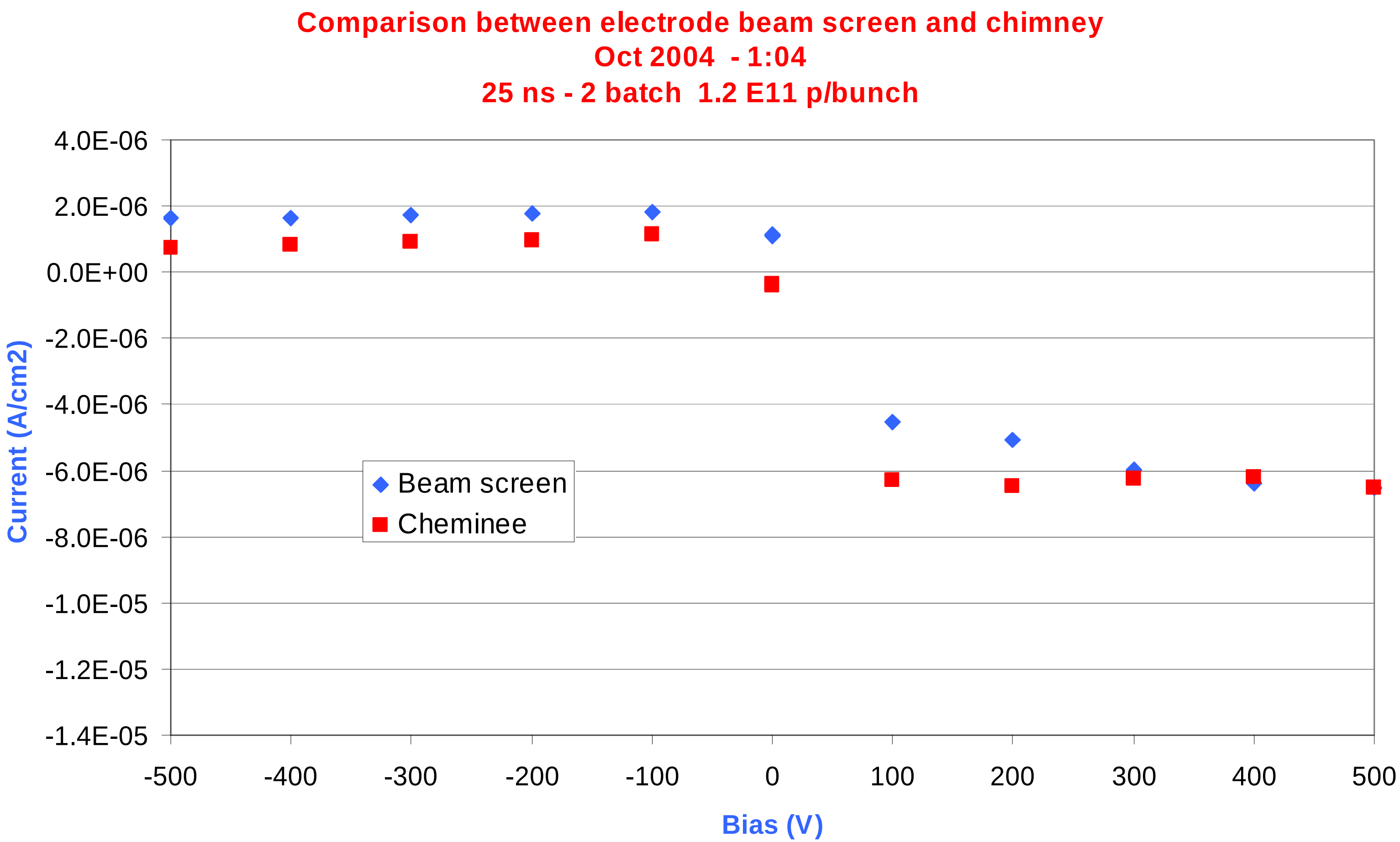
- The power measured with the WAMPAC 4 and COLDEX are the same

4. Electron cloud current

Comparison of electrodes current

2 batches : the collected current is the same for both electrode

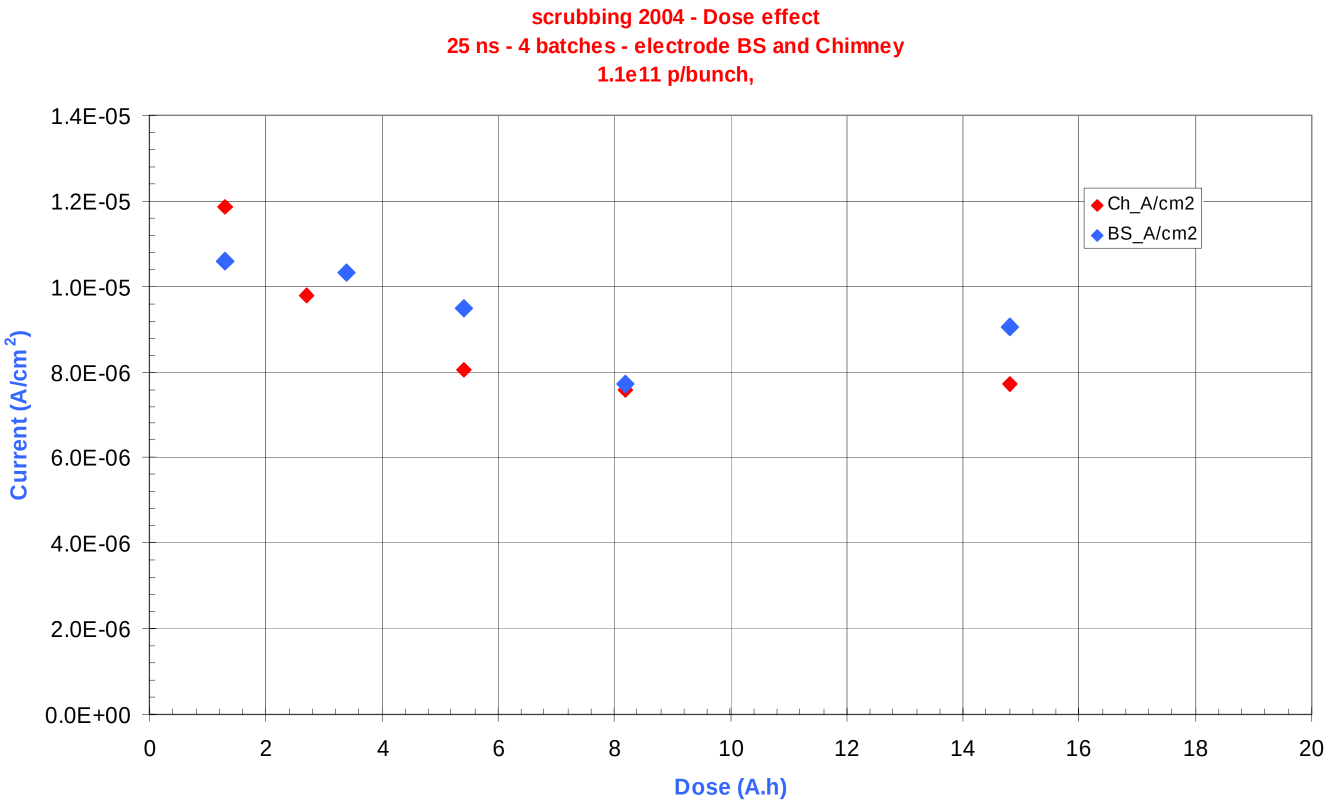
The SPS valves were opened 1day before the measurement
(a deliberate pressure increase of 1000 at one extremity is not seen in the centre)



Electron current

Corresponding power for 100 eV :

- 75 ns : 1.9 µA — 0.2 W/m
- scrubbing at 25 ns : starts at 25 µA to end at 15 µA — 2.4 to 1.4 W/m
- after the scrubbing run, 75 ns = 0.1 µA — 0.0 W/m

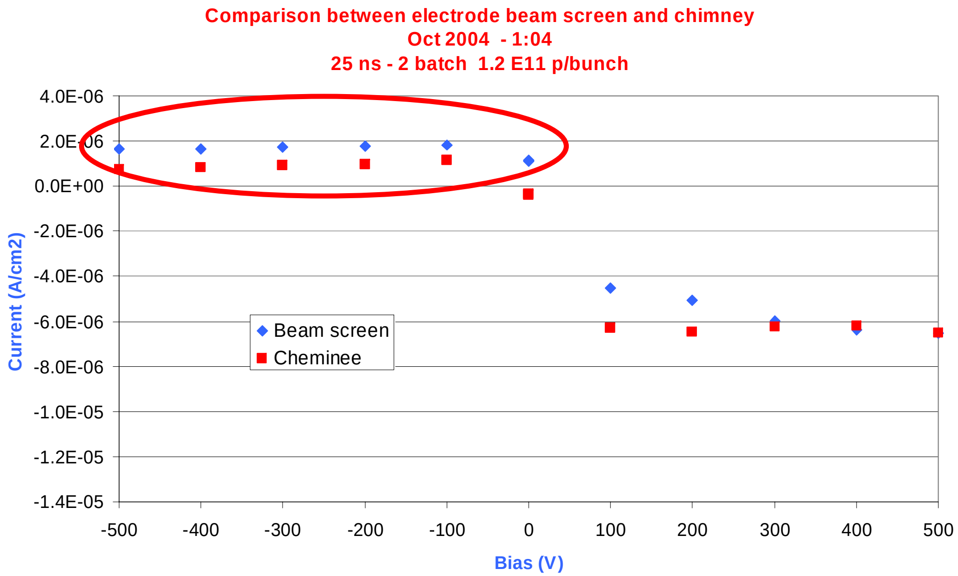


4. Ion current

- The positive signal could be interpreted as an "ion current"

- It can be shown that this is an artefact of the measurement device

- The positive current is due to the contribution of secondary electrons which are leaving the electrode



- So, no "ion current" were measured with COLDEX

Estimation of the expected ion current
In the SPS

- Primary ionisation :

σ_p = 2 10^{-22} m^2 for CO
P = 10^{-9} Torr at 300 K
T = 12 K
I_{beam} = 0.2 A

$$I_P = \sigma_P \frac{P}{kT} I_{beam} = 7\ \text{nA/m}$$

- Secondary ionisation :

σ_s = 1.2 10^{-20} m^2 for CO
P = 10^{-9} Torr at 300 K
T = 12 K
I_e = 15 mA/m
L_e ~ 0.1 m

$$I_e = \sigma_s \frac{P}{kT} L_e I_e = 3\ \text{nA/m}$$

For similar values the vacuum stability threshold is divided by 2

Electron path length is unknown !

Estimation of the expected ion current

In the LHC

- Primary ionisation :

$\sigma_p = 2\ 10^{-22}$ m^2 for CO
P = 10^{-9} Torr ~ 10^{-7} Pa
T = 15 K
I_{beam} = 0.6 A

$$I_P = \sigma_P \frac{P}{kT} I_{beam} = 20\ \text{nA/m}$$

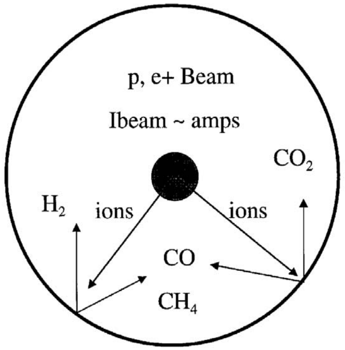
If the electron path length is 1 order of magnitude larger, the effects are similar :
=> Electron cloud could affect LHC vacuum stability

- Secondary ionisation :

$\sigma_s = 1.2\ 10^{-20}$ m^2 for CO
P = 10^{-9} Torr ~ 10^{-7} Pa
T = 15 K
L_e ~ 0.1 m
P = 1 W/m
<E> = 100 eV
I_e = 10 mA/m

$$I_e = \sigma_s \frac{P}{kT} L_e I_e = 2\ \text{nA/m}$$

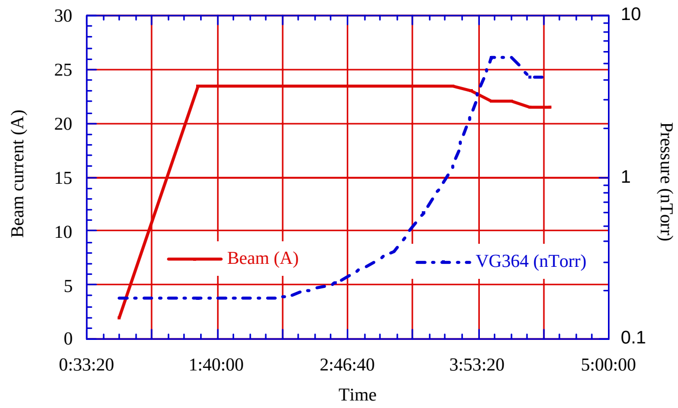
Ion induced beam instability



$$P = \frac{Q}{S - \eta_{Ions}\sigma \frac{I}{e}}$$

Reduction of net pumping speed

$$(\eta_{Ions} I)_{crit} = \frac{eS}{\sigma}$$



Pressure instability during beam stacking in the ISR.

Stability in cryogenic elements

- Beam screen hole's pumping; $(\eta_{ion} I)_{crit}$ ~ 20 to 10^3 A

Stability in room temperature elements

- NEG coating is expected to provide low η_{ion} yield (< baked surface)
- Adequat combinaison of NEG pumping + sputter ion pumping ensure required pumping speed

6. Conclusions

Pressure

- Total pressure increase, ~ 3 10^{-9} Torr with 25 ns bunch spacing, 2 batches and 5 days operation

- Residual gas dominated by

  H_2 = 2 10^{-9} Torr

  CO = 1 10^{-9} Torr

6. Conclusions

Heat load

- Evidence of a threshold at 7 10^{10} p/bunch
- After 12h with 0.5 or 1 W/m the SEY should be in the range 1.2 -1.4
- Heat load onto the BS, ~ 0.8 W/m with 25 ns bunch spacing and 2 batches

6. Conclusions

Electron current

- The collected current is the same for both electrodes

- At 25 ns, the collected current is decreased with dose form 12 to 8 $\mu A/cm^2$

6. Conclusions

Ion current

- No ion current were measured in COLDEX

- In the SPS, the ion currents due to ionisation by the proton beam and to ionisation by the electron cloud are similar

- In the LHC, for large electron path length (1 m), the ion currents due ionisation by the proton beam and to ionisation by the electron cloud could be similar

- Possible consequences on vacuum stability