Electron cloud activities for CLIC and the SPS-U Study Team

G. Rumolo, LIS Meeting (05/10/2009)

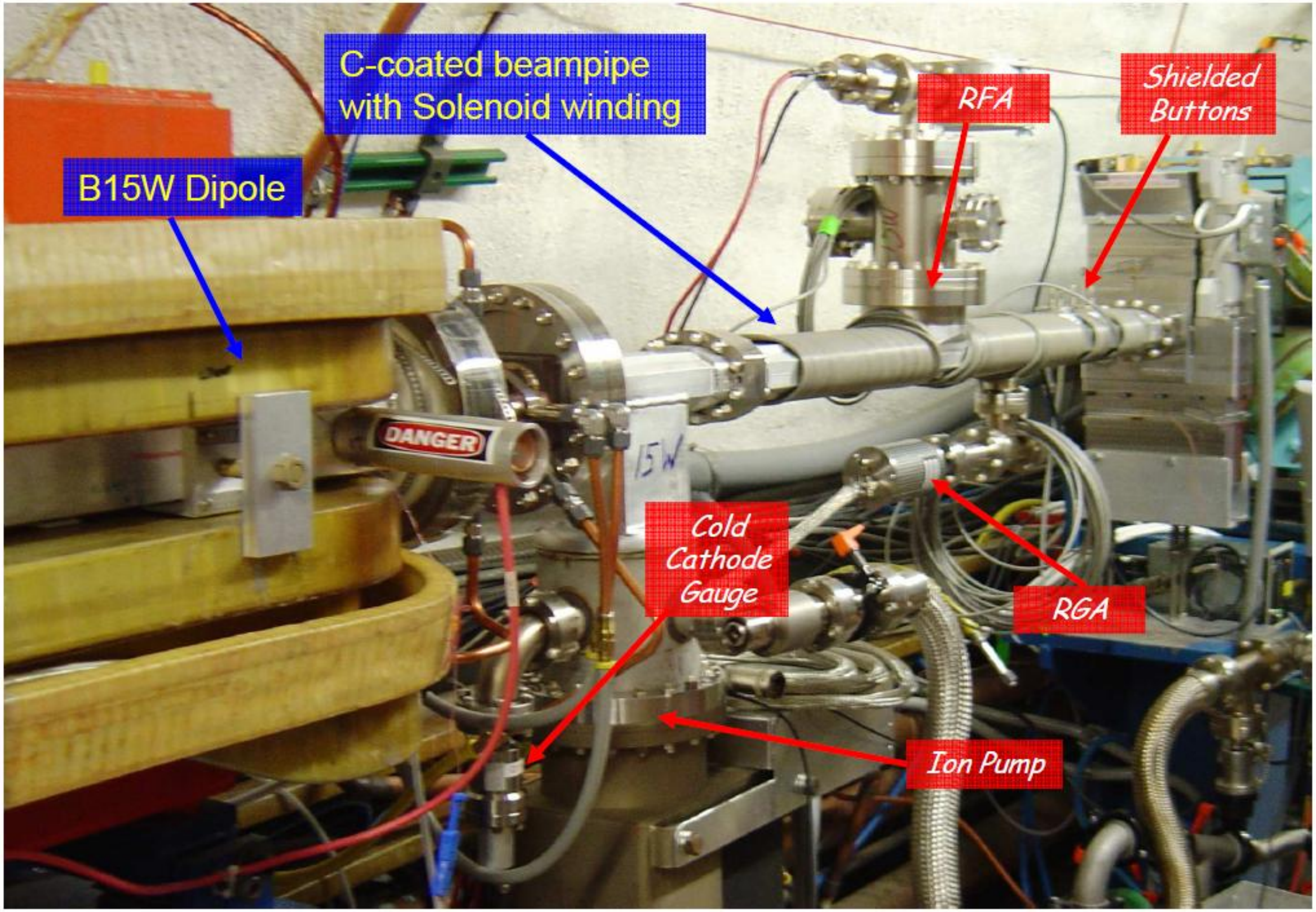
- Testing C-coated chambers in a lepton machine:
  - C-coated chambers in Cesr-TA
  - Electron cloud measurement campaign during the July-August run of Cesr-TA
- SPS measurements and ECLOUD simulations:
  - Liner measurements: dependence on the magnetic field
  - Influence of the holes in the measurement
  - Results of ECLOUD simulations: difference between perturbed and unperturbed geometries

$\Rightarrow$ With the contribution of the SPS-U Study Team and the support of the CLIC studies

Coating for Cesr-TA

- June 2008: First suggestion from M. Tigner (during LHC MAC, presentation by P. Chiggiato)
- June 2008: GR & S. Calatroni take part to ILCDR08, and the CERN interest started
- August (?) 2008: start of formal CLIC-ILC collaboration on damping rings (Yannis Papaphilippou & Mark Palmer)
- November: 2008 (ECM’08): definition of program and of a possible test chamber
- May 2009: Shipping of test chamber to CERN
- June 2009: Carbon coating, shipping back and installation in Cesr-TA
- July-August 2009: first measurements with the newly installed C-coated chamber

Q15W RFA Installed in CESR on 7/1/2009

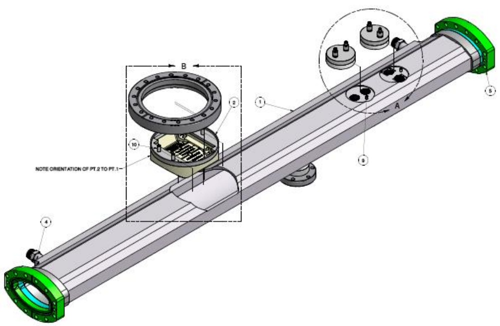


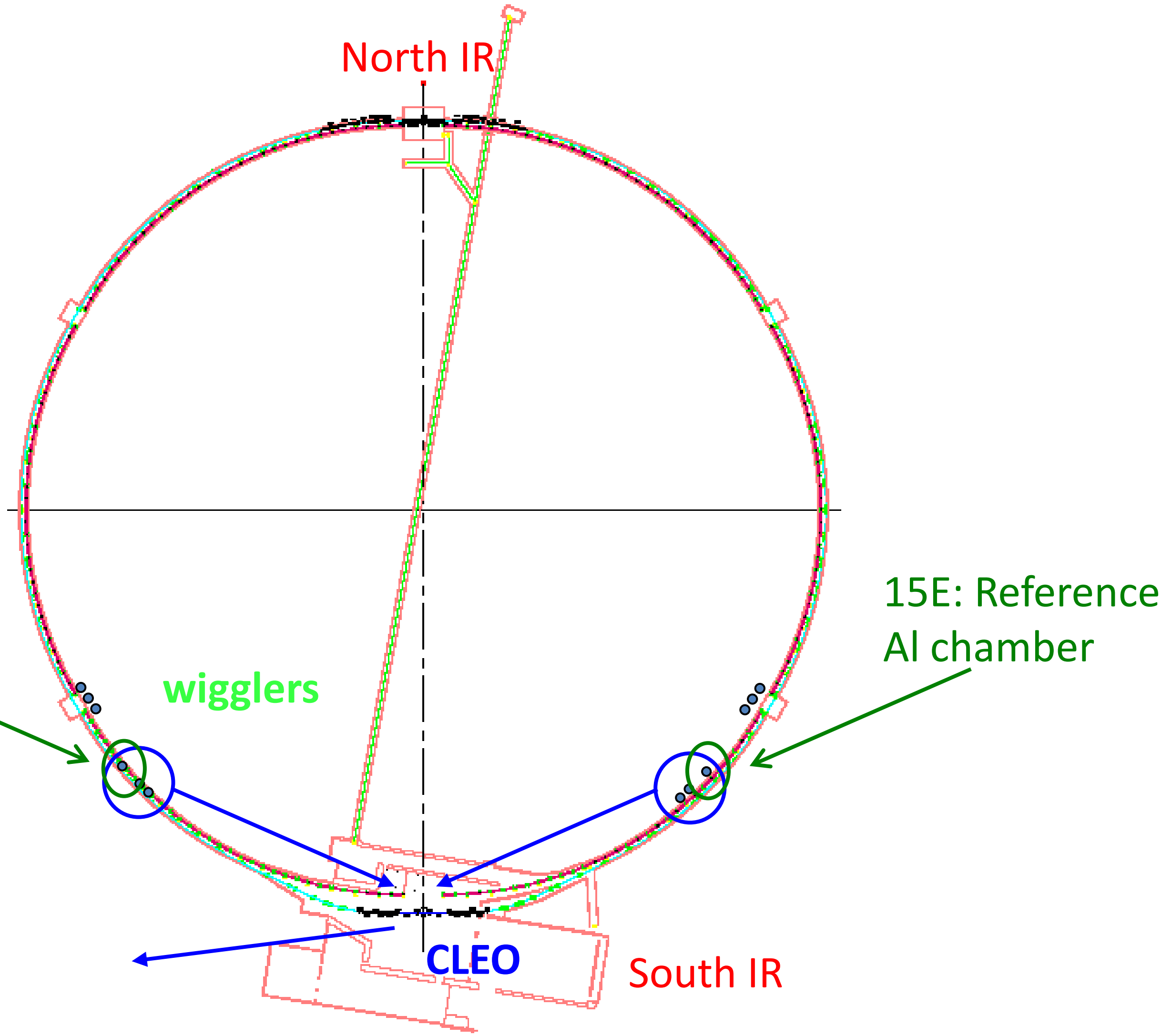
Initial SEY of a-C coating = 0.98 (measured on witness samples)

A quick glance to the CesrTA target parameters...

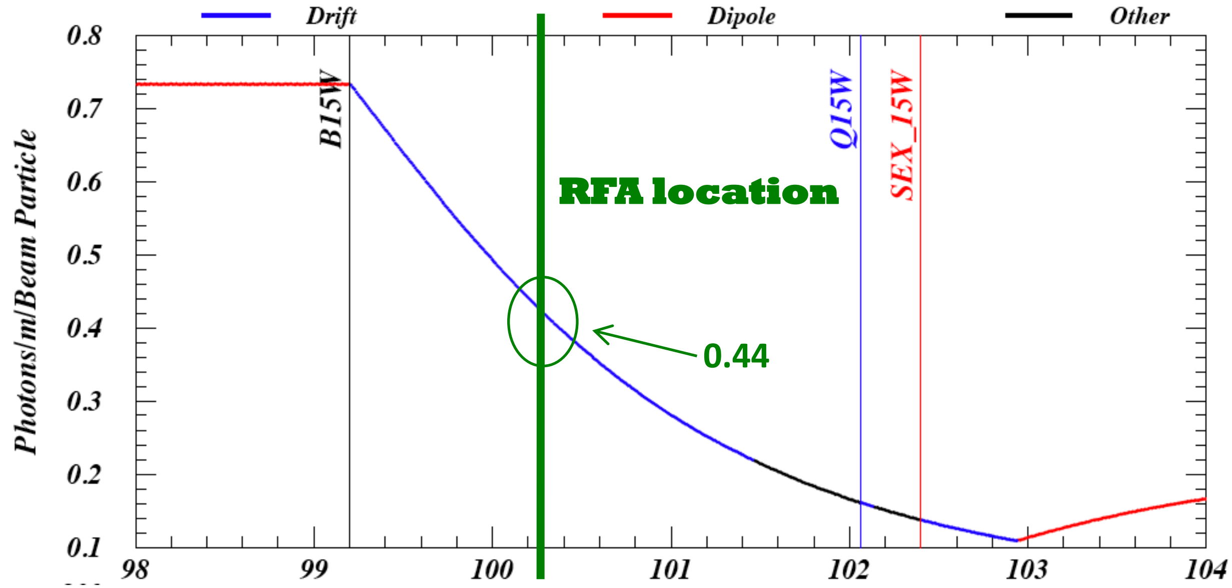
Parameter	***Value***
Energy	1.9 - 5.3 GeV
No. wigglers	12
B_{max}	2.1 T
ε_x (geometric)	2.25 nm
ε_y (geometric)	20 pm (~40 nm normalized)
Q_x	0.59
Q_y	0.63
Q_z	0.070 - 0.098
σ_z	6.8 - 8.9 mm
$\Delta E/E$	8.1 - 8.6 x 10^{-4}
Rf voltage	7.6 MV
$\tau_{x,y}$	~ 60 ms
α_p	6.2 x 10^{-4}
N_b	1 - 2 x 10^{10}
Bunch spacing	Multiples of 4 ns and 14 ns

CESR Modifications

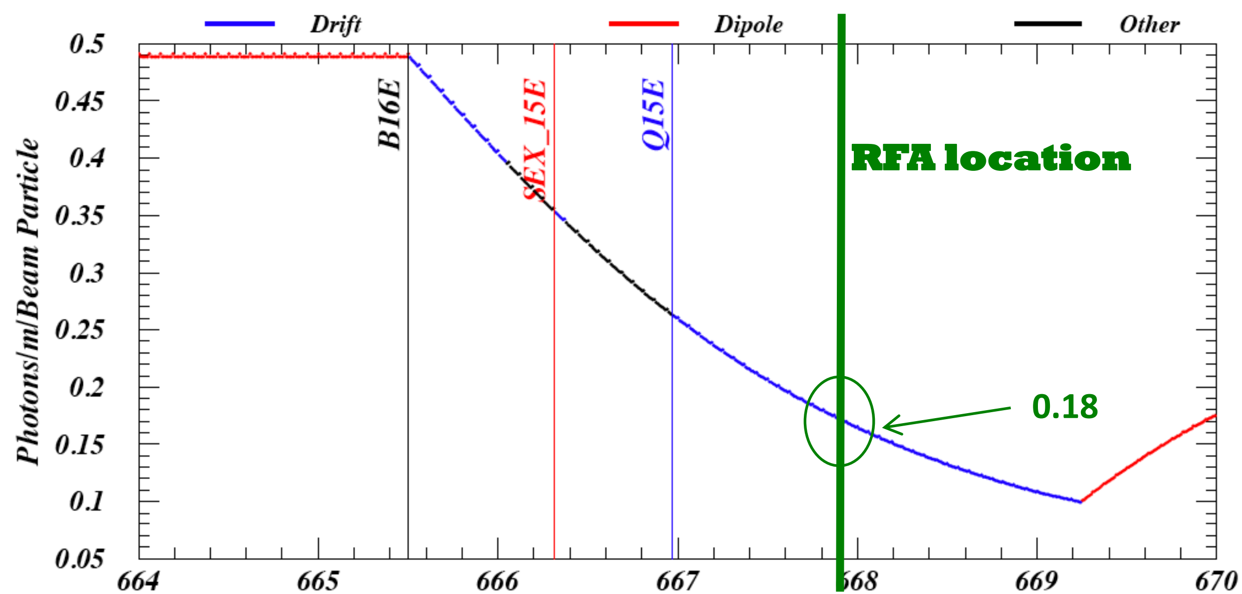




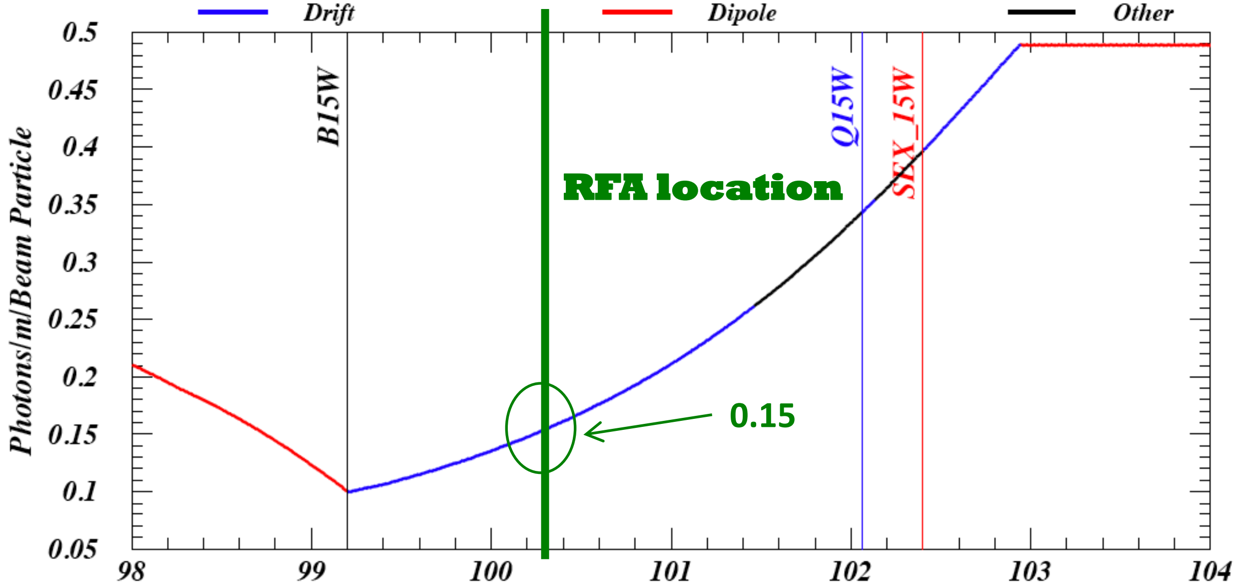
15W, positrons, 2 GeV



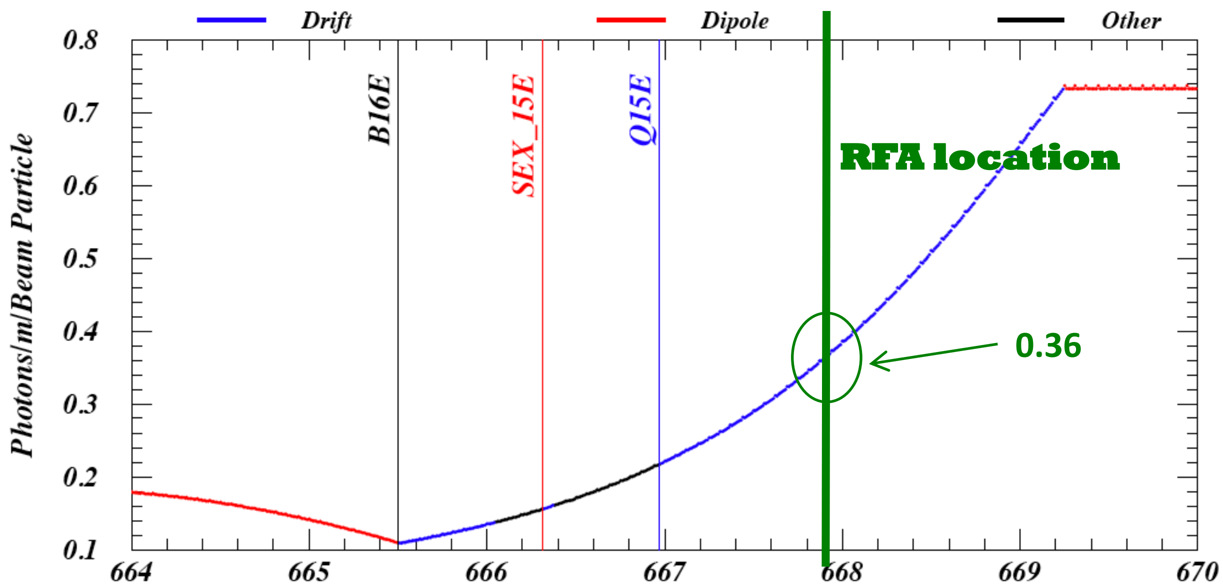
15E, positrons, 2 GeV



15W, electrons, 2 GeV

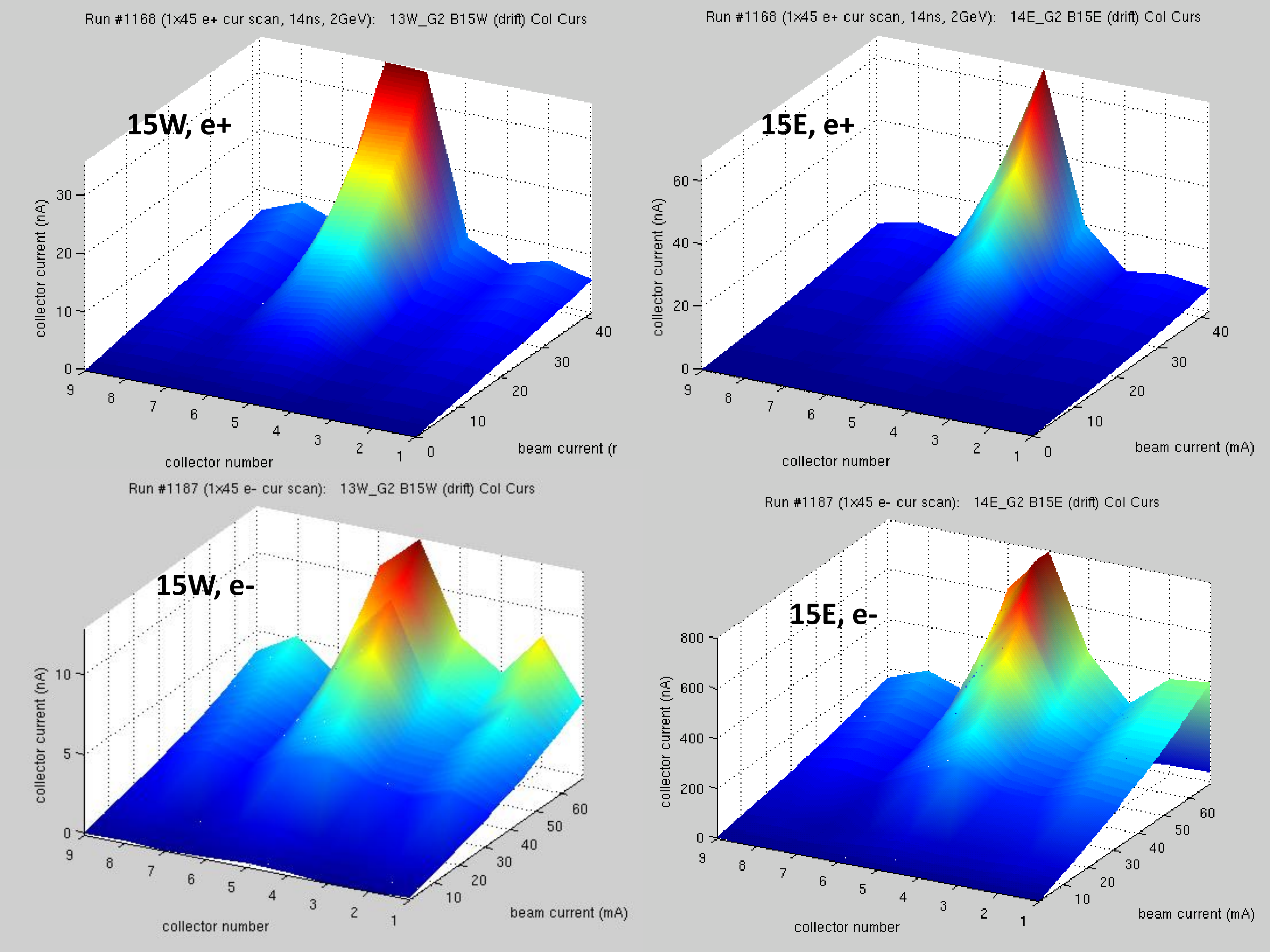


15E, electrons, 2 GeV



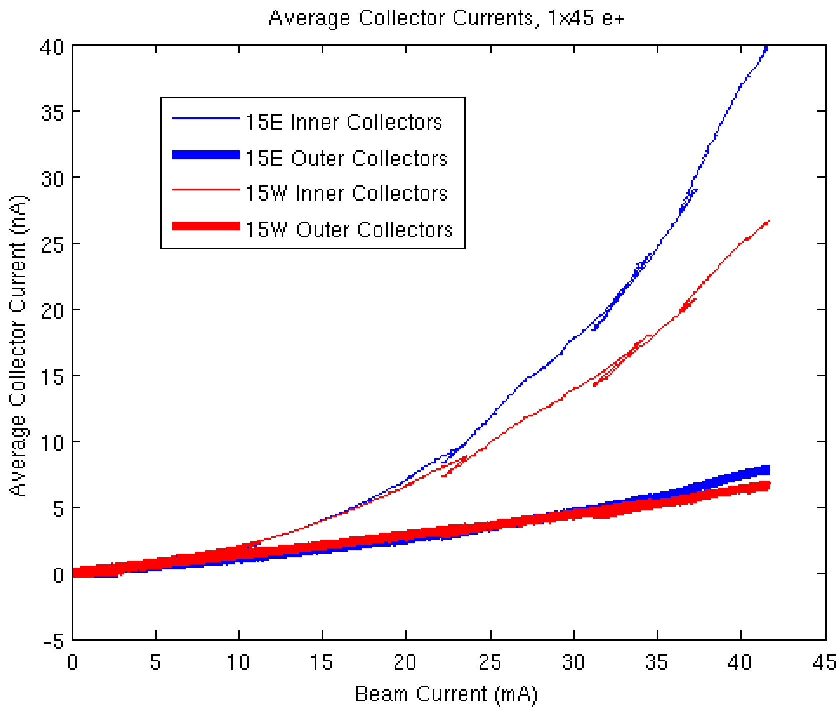
15W vs 15E Current Scans

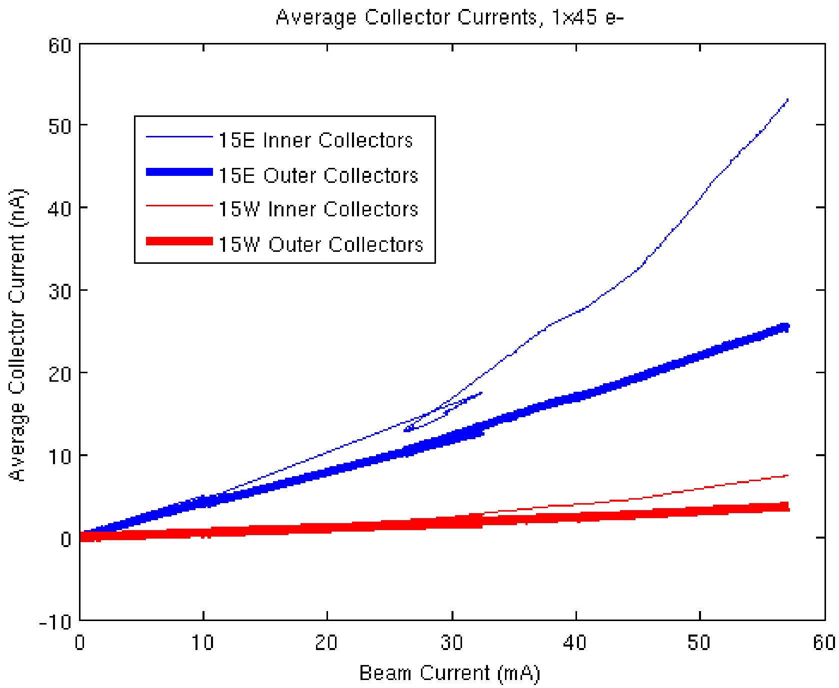
- 15W: Carbon coated, sees more radiation for e^+ (see previous slides)
- 15E: Uncoated Al, more radiation for e^- (see previous slides)
- Several intensity scans were done on 26/07/2009 and 28/07/2009, when data were acquired with a 45 bunch train, 14ns spacing, 2 GeV: Comparison of e^+ and e^-, comparison of Sunday and Tuesday's scans.
- Intensity scans on 30/07/2009 with a 45 bunch train of e^+, 14ns spacing, 5 GeV
- Data from 01/08/2009, solenoid in 15W on and off, dogleg in 15W (15E?) off and on, different bunch spacings.



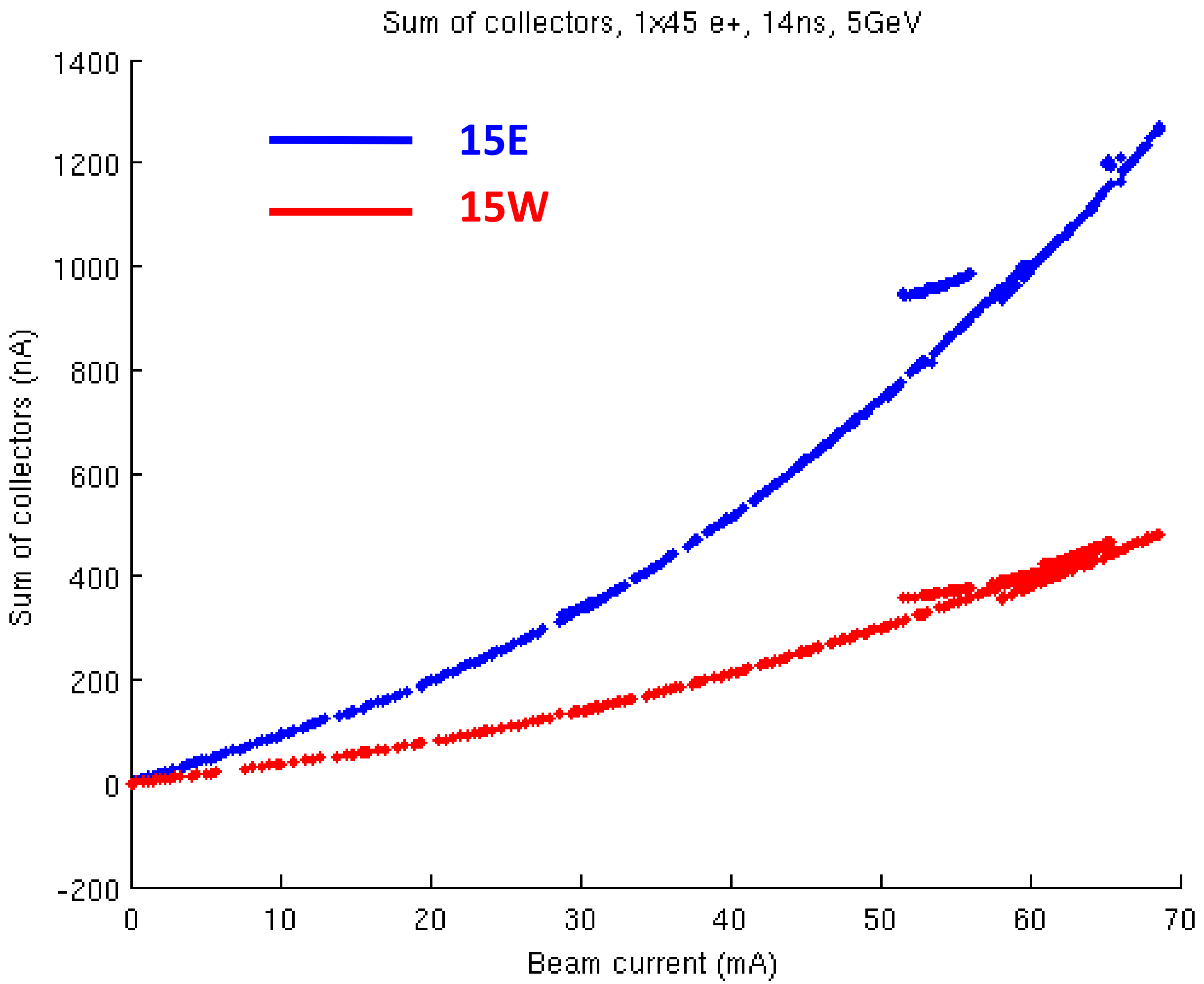
Run #1168 (1x45 e+ cur scan, 14ns, 2GeV): 13W_G2 B15W (drift) Col Curs
15W, e+
collector current (nA)
collector number
beam current (r
Run #1168 (1x45 e+ cur scan, 14ns, 2GeV): 14E_G2 B15E (drift) Col Curs
15E, e+
collector current (nA)
collector number
beam current (mA)
Run #1187 (1x45 e- cur scan): 13W_G2 B15W (drift) Col Curs
15W, e-
collector current (nA)
collector number
beam current (mA)
Run #1187 (1x45 e- cur scan): 14E_G2 B15E (drift) Col Curs
15E, e-
collector current (nA)
collector number
beam current (mA)

- Plots show mean of inner 3 collectors (4,5,6) and outer 6 collectors (1,2,3,7,8,9) for positrons (left) and electrons (right)
  - Outer collectors ~ primary photoelectrons
  - Inner collectors ~ primaries + secondaries (?)





- Run with positrons at 5 GeV, intensity scan (Thursday 30/07/2009): sum of all the collector channels



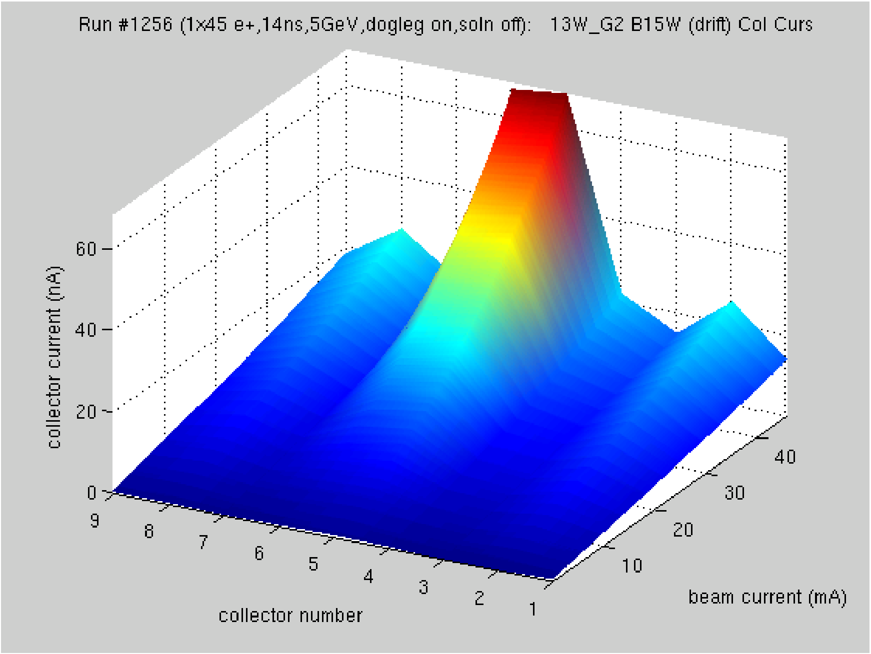
Run with positrons at 5 GeV on Saturday 02/08/2009. Several intensity scans. Main studies which were done:

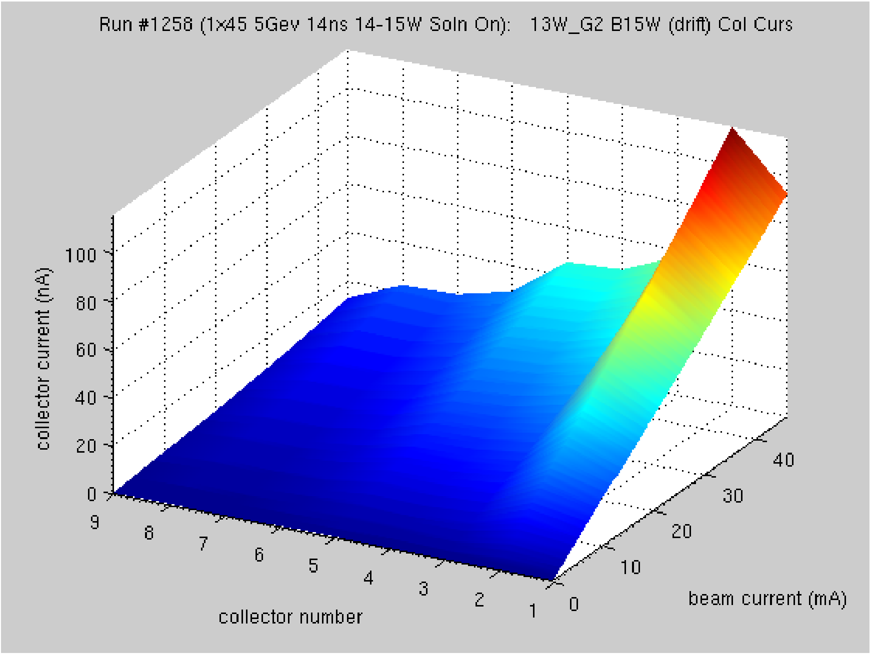
1. Dogleg in 15W on and off. The dogleg is a short dipole with 100G field between the C-coated chamber and the dipole upstream. Its purpose is to avoid contamination from the electrons upstream.
2. Solenoid in 15W on and off
3. Change bunch spacing from 14 to 28ns and make a train of 75 bunches (instead of 45)
4. Monitor the electrons with 9 bunches almost perfectly uniformly distributed around the machine (3 x (280/280/294))

Pending:

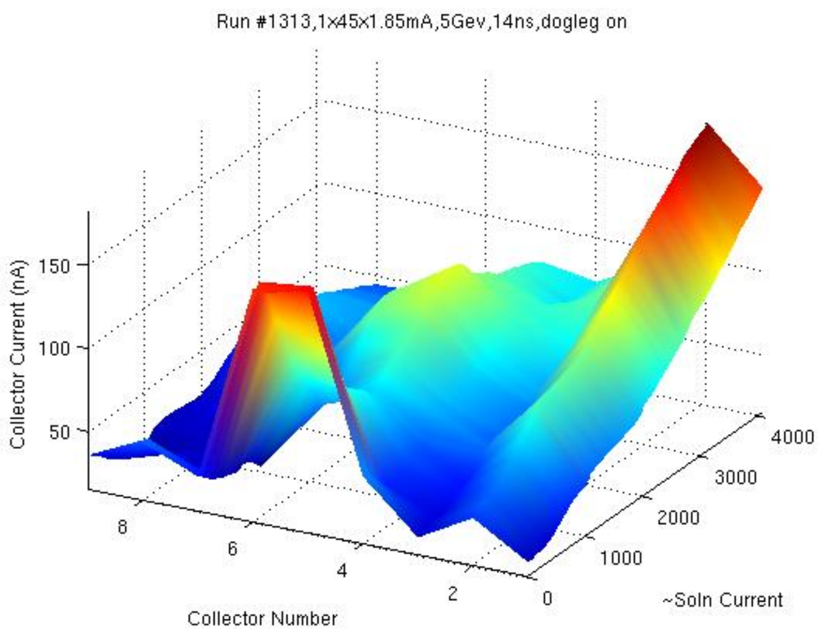
- Decrease bunch spacing (to 4 ns)
- Run with e^- at 5 GeV

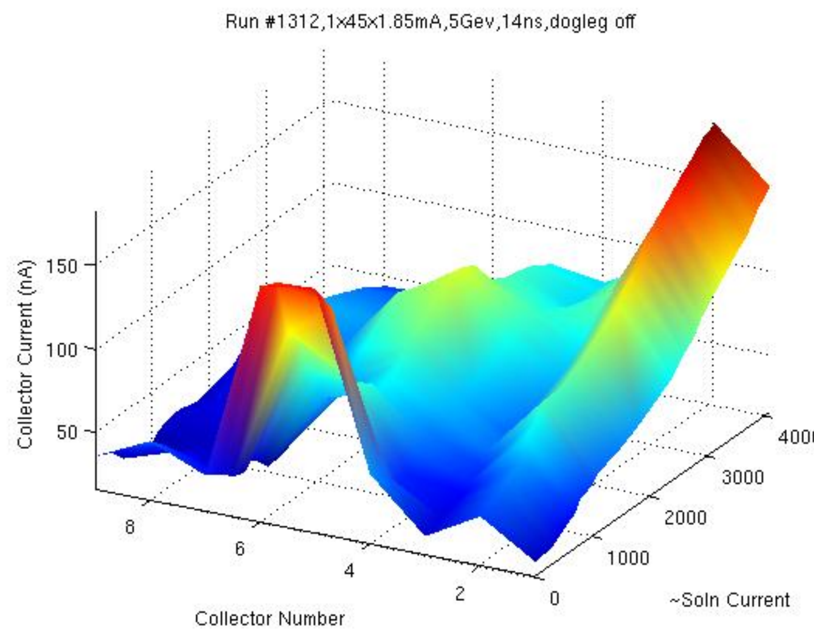
- Run with positrons at 5 GeV, intensity scan (Saturday 02/08/2009): comparing data from intensity scan with solenoid in 15W off and on (no change in 15E). There is a change in the electron distribution in the collectors



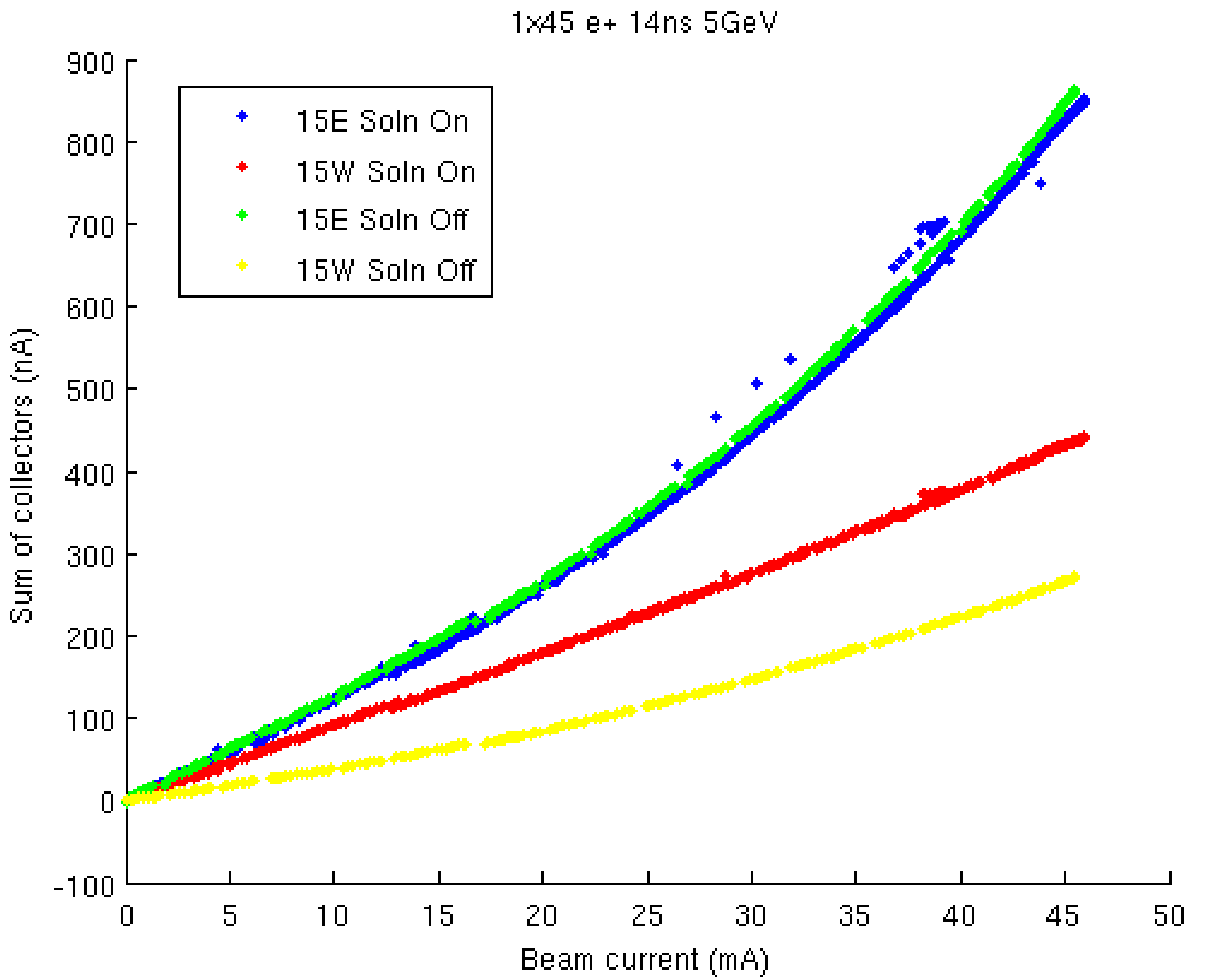


- Run with positrons at 5 GeV, data from solenoid field scan: the shape of the electron distribution changes while increasing the intensity of the B-field (4000 -> 70 G)

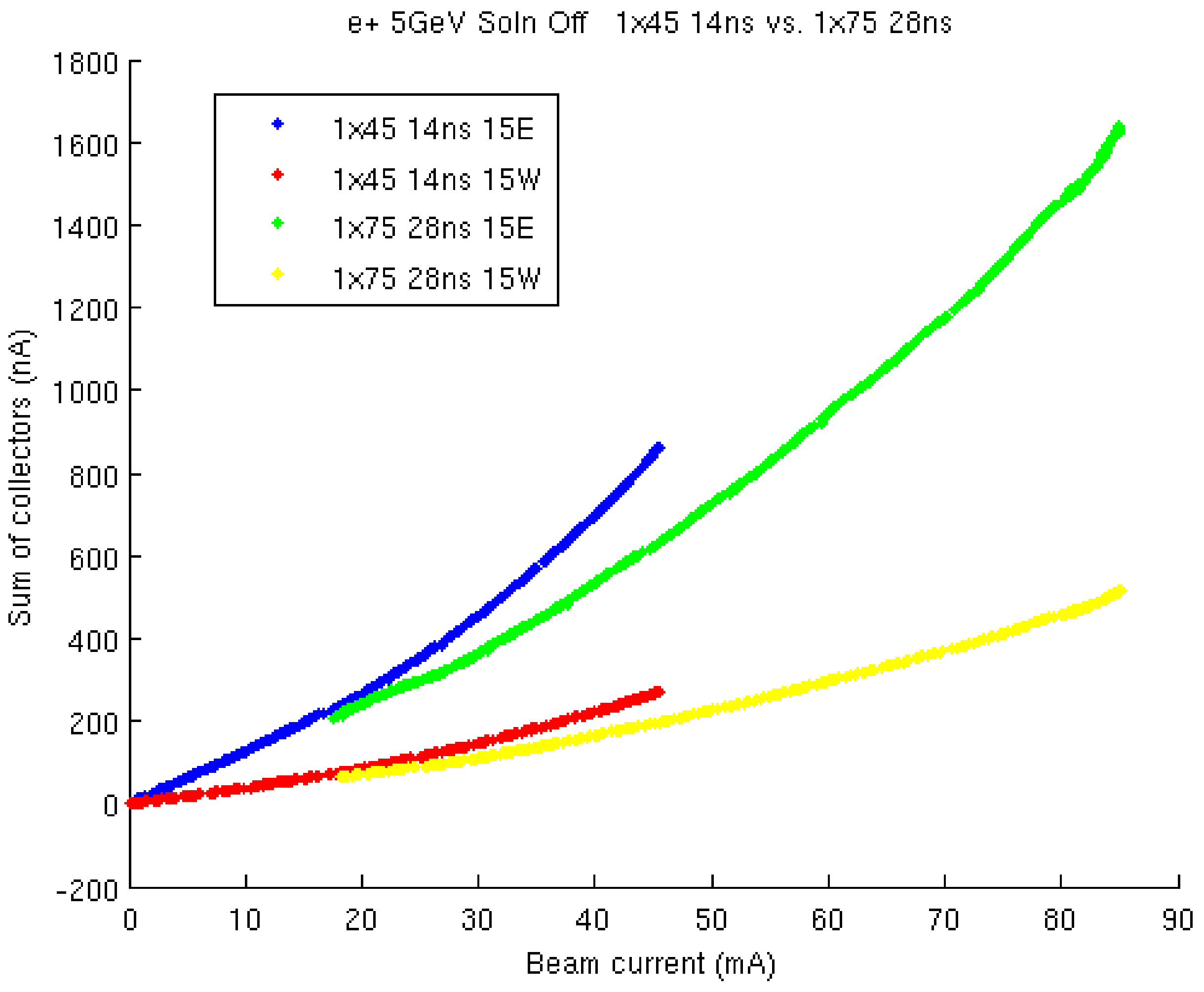




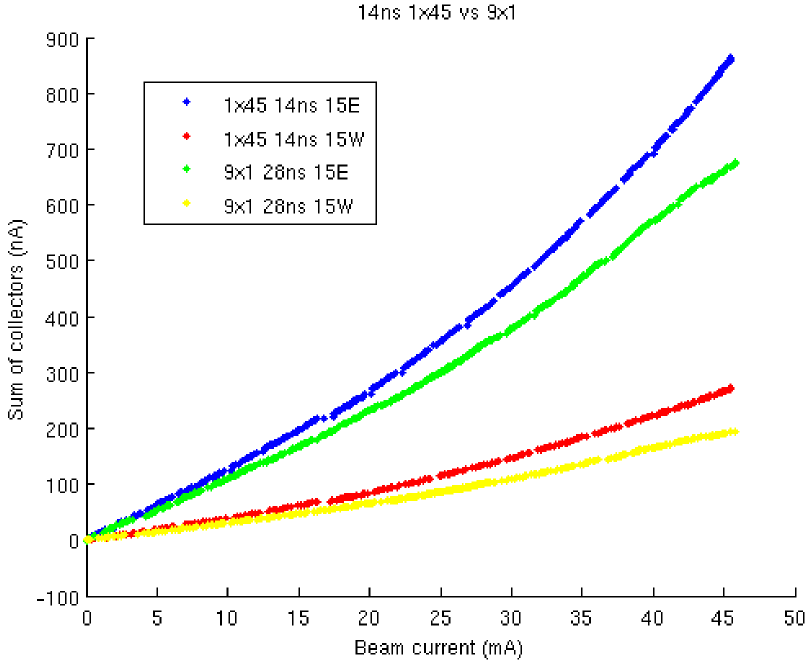
- Run with positrons at 5 GeV, intensity scan (02/08/2009): comparing data from intensity scan with solenoid in 15W off and on (no change in 15E)

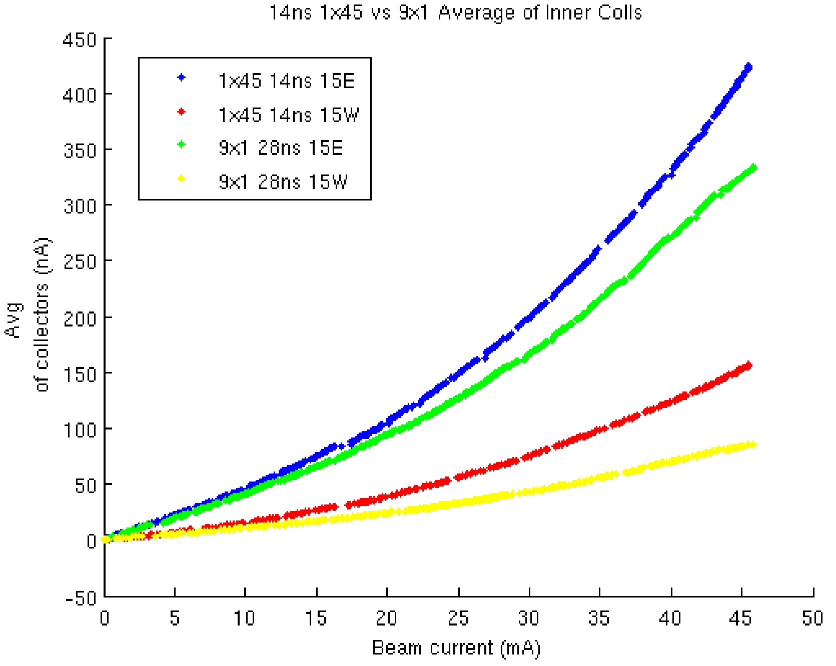


- Run with positrons at 5 GeV, intensity scan (02/08/2009): comparing data from intensity scan with solenoid off and two bunch spacings and train lengths (45 x 14 ns, 75 x 28 ns)

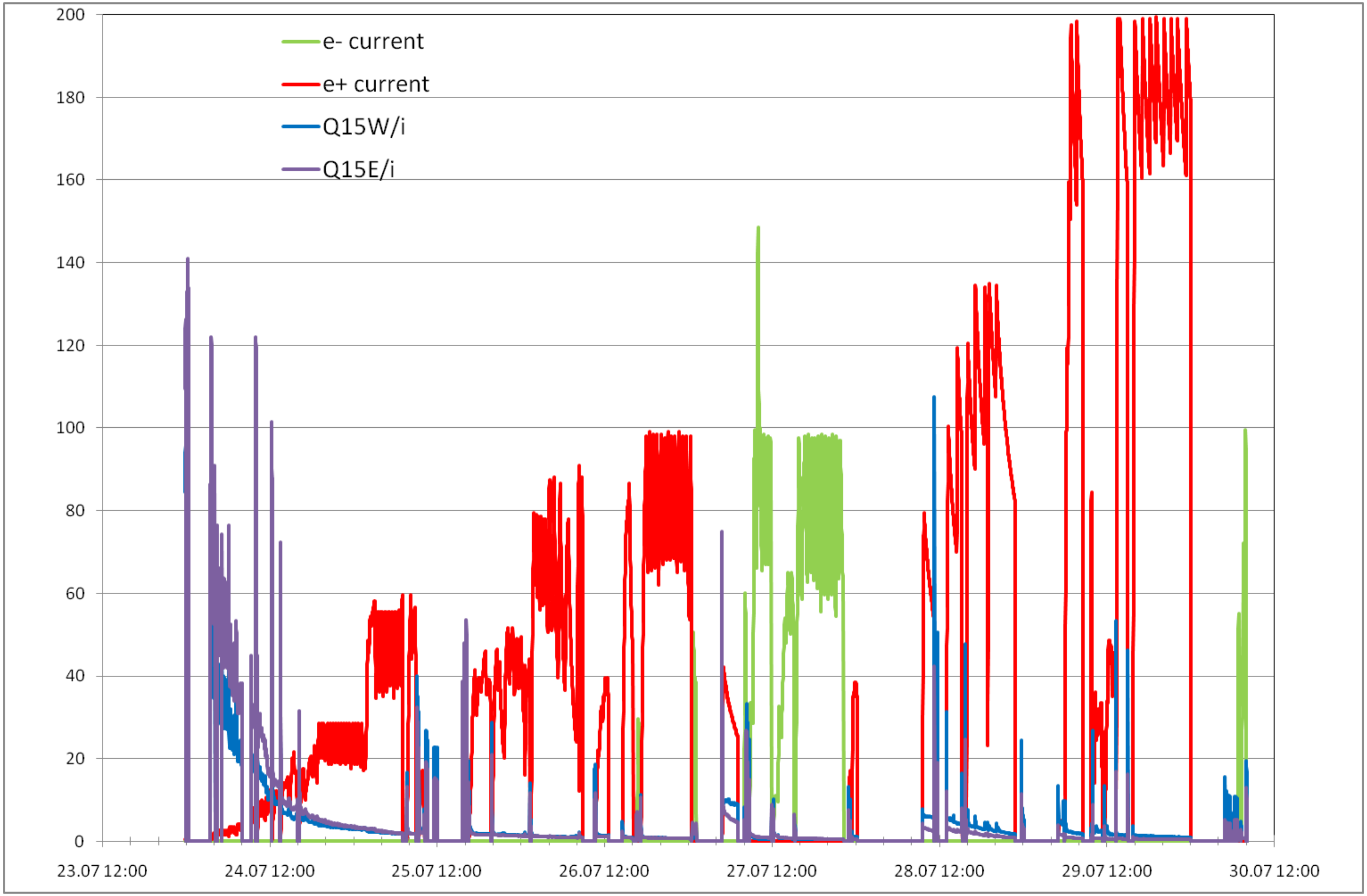


- Run with positrons at 5 GeV, intensity scan (02/08/2009): comparing data from intensity scan with solenoid off and two bunch spacings and train lengths (45 x 14 ns, 9 x 280 ns). Both the sum of all channels and only the sum of the inner collectors are displayed.



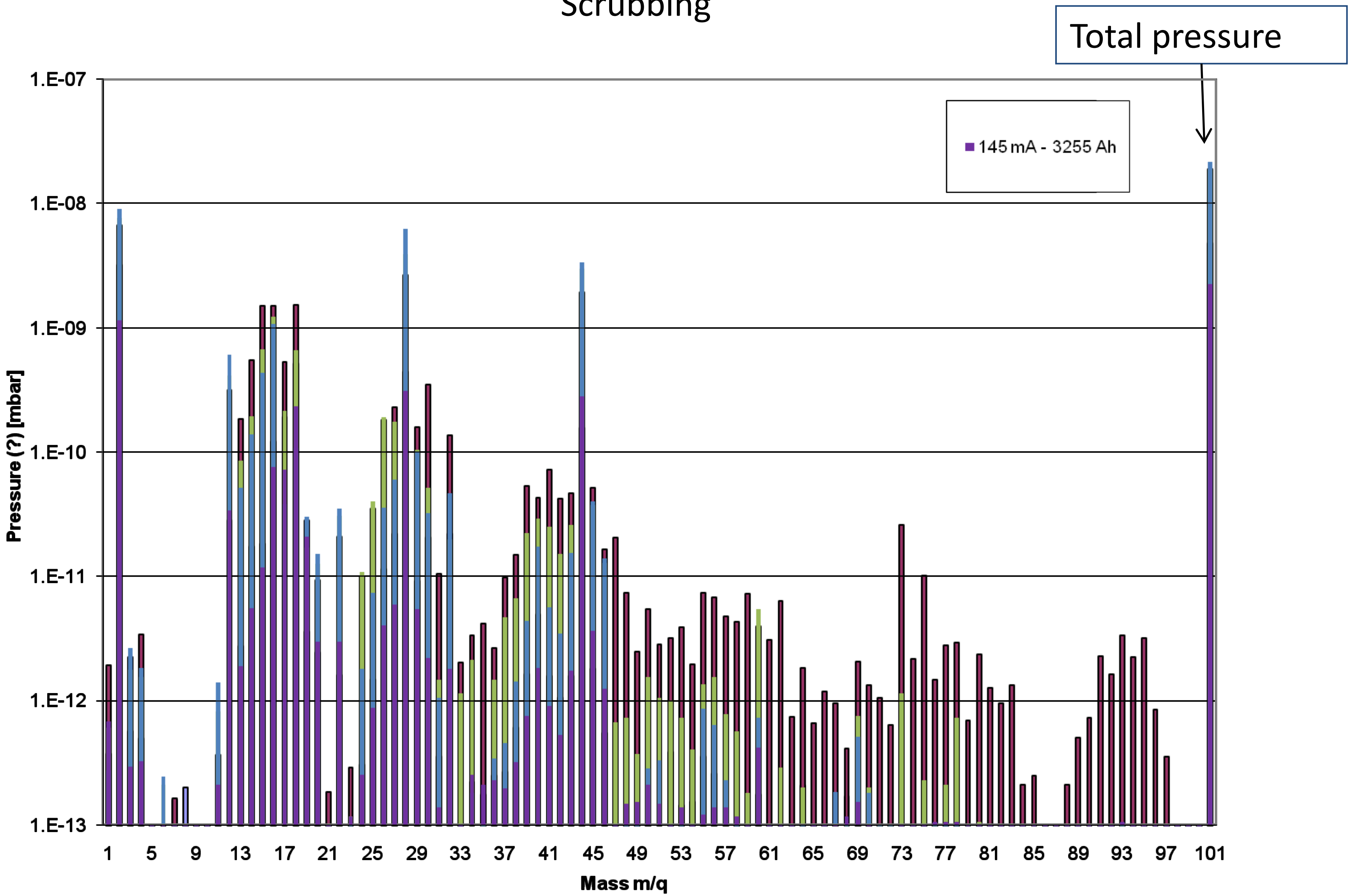


Scrubbing



e- current
e+ current
Q15W/i
Q15E/i
200
180
160
140
120
100
80
60
40
20
0
23.07 12:00
24.07 12:00
25.07 12:00
26.07 12:00
27.07 12:00
28.07 12:00
29.07 12:00
30.07 12:00

Scrubbing



Total pressure
145 mA - 3255 Ah
1.E-07
1.E-08
1.E-09
1.E-10
1.E-11
1.E-12
1.E-13
Pressure (?) [mbar]
1 5 9 13 17 21 25 29 33 37 41 45 49 53 57 61 65 69 73 77 81 85 89 93 97 101
Mass m/q

- Before installation in Cesr-TA the Vacuum Lab performs acceptance tests by baking at 150 ° C
  - ✓ It is possible that the use of adhesive tape has contaminated with Si the inner wall of the chamber. Tests at CERN are supportive of this possibility
  - ✓ The RGA shows in the 15W chamber peaks for the masses of H_2, C, CO, CO_2, CH_4, H_2O, and various hydrocarbons at lower level, but no signs of Si-containing residual gases. It is possible that the contamination contributes with levels of Si in order of 10^{-13} partial pressure when degassed, which is invisible to the RGA but can change significantly the surface properties.

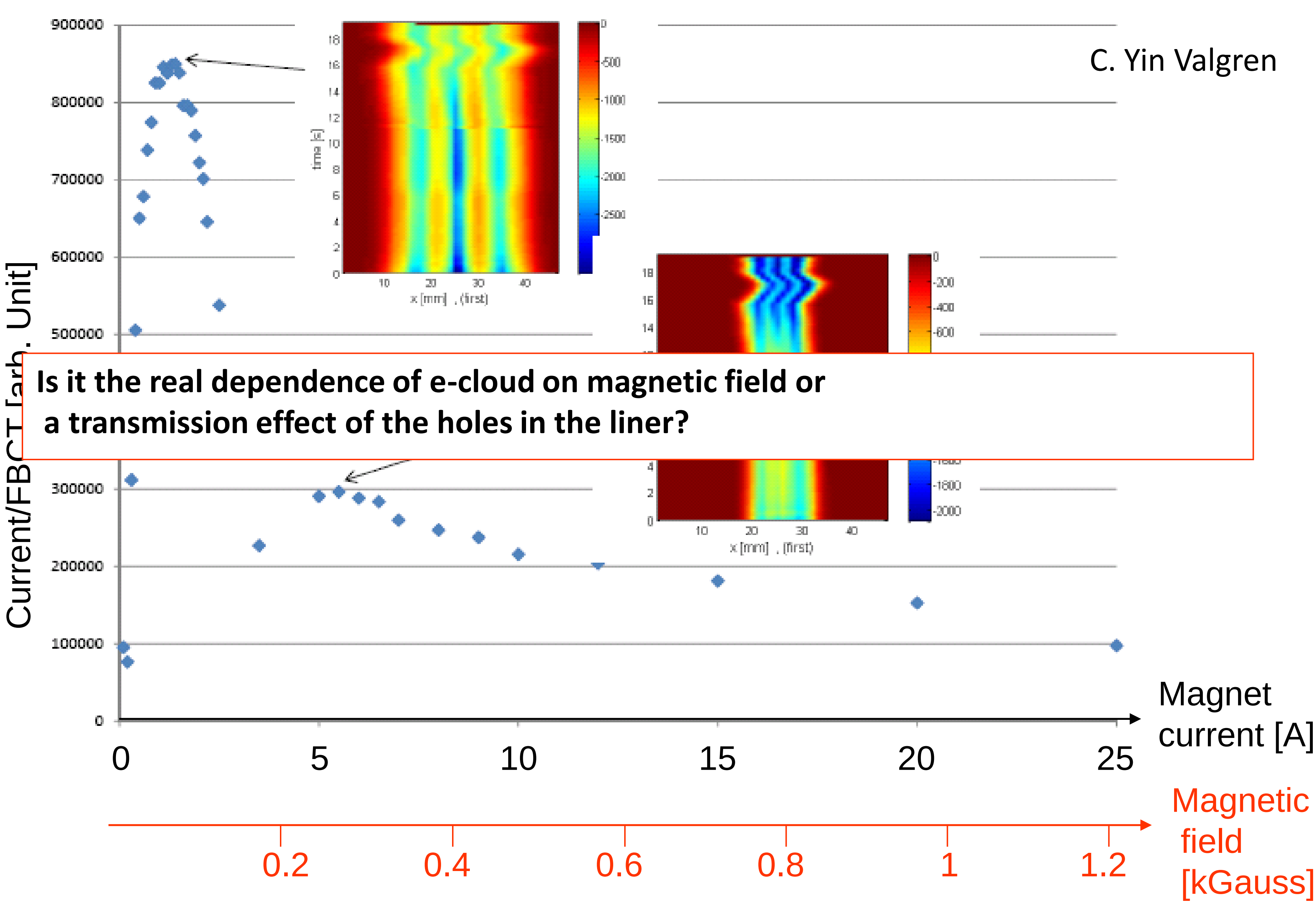
- However, do we really see the effect of the SEY in the electrons measured by the RFA, or are we only dominated by photoelectrons?
  - ✓ The nonlinear behavior of the electron flux measured over an intensity scan seems to suggest that there is multipacting, at least in the central part of the chamber
  - ✓ Preliminary ECLOUD simulations do not predict multipacting dominated electron cloud for SEYs up to 2.0. It appears that the nonlinear behavior of the electron flux as a function of the beam current in the central region of the chamber can also occur for an electron cloud dominated by photoelectrons. Perhaps a better modeling of the RFA in simulations is needed.
  - ✓ Comparison of values of RFA current between bare aluminum chamber and the carbon coated one during e^- runs indicate the lower photoemission yield of the latter by a factor larger than 2.

Motivations of the study

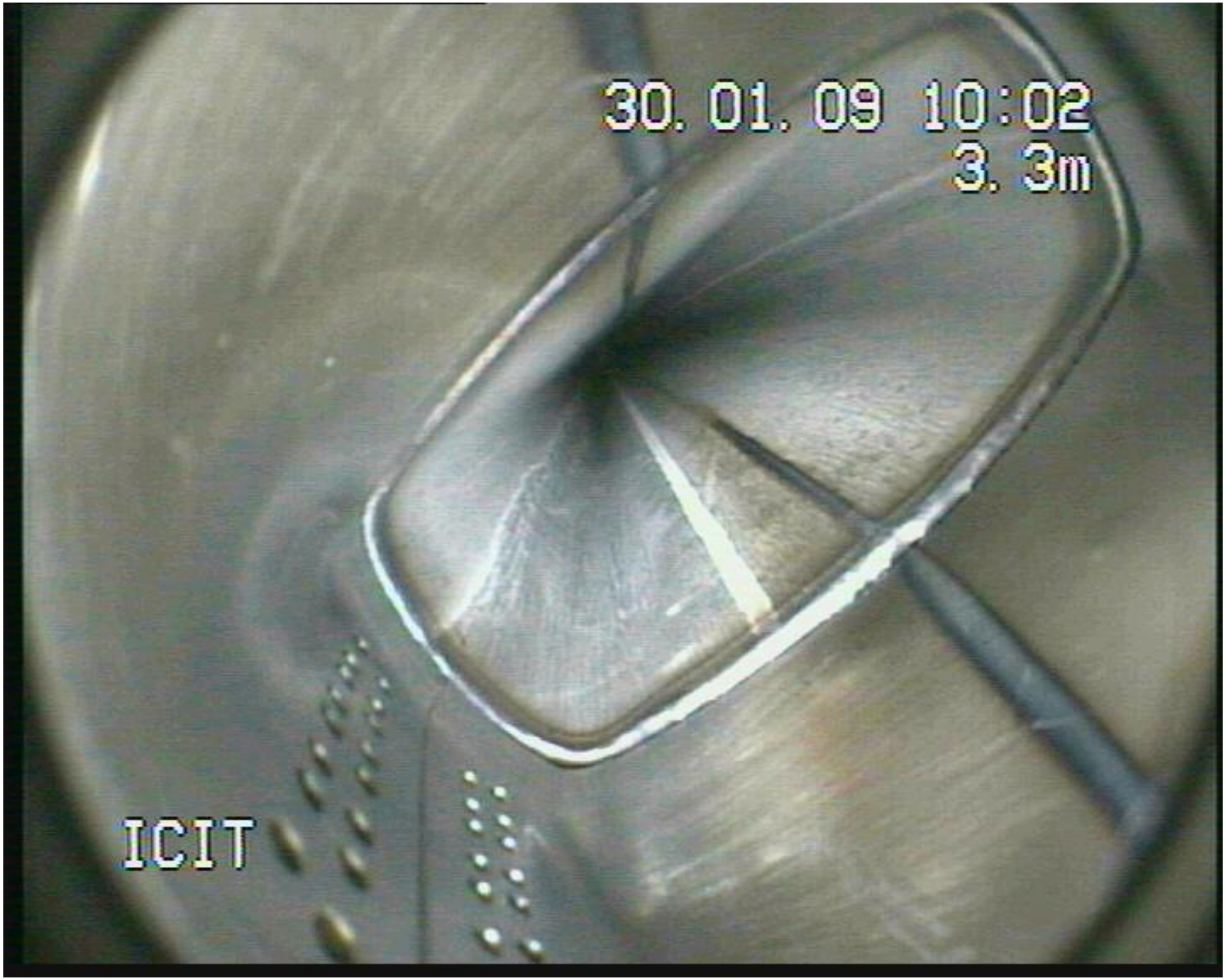
- During the SPS long MD of week 32, it was decided to carry out **a systematic study of the behavior of the measured electron cloud in the StSt liner as a function of the magnetic field**.
- Surprisingly enough, the measured signal seemed to indicate the presence of a denser electron cloud for low values of magnetic field.
- This behavior had been observed before and was qualitatively ascribed to a local electron cloud suppression at the hole locations. When the magnetic field is strong enough that the Larmor radius of the electron motion becomes smaller than the hole radius, multipacting is locally suppressed because the electrons are swallowed by the holes and not multiplied in the chamber (G. Arduini et al., PAC'01)
- However, in absence of quantitative analysis, this observation led to the belief that there could be really more electron cloud in regions with low magnetic field, e.g. in the fringe field regions of the bending magnets, where the magnetic field rapidly varies from the nominal dipole value to zero (or vice versa)
- The idea appeared to find a strong confirmation in that most of the SPS vacuum chambers exhibit a clear central black mark, possibly attributed to e-cloud heating, over a region extending for only about 0.5m at the entrance and at the exit of the magnets

→ **ECLOUD could be used to simulate the effect of the hole in the pipe wall….**

E-cloud monitor as a function of B. Stainless steel liner



Is it the real dependence of e-cloud on magnetic field or a transmission effect of the holes in the liner?



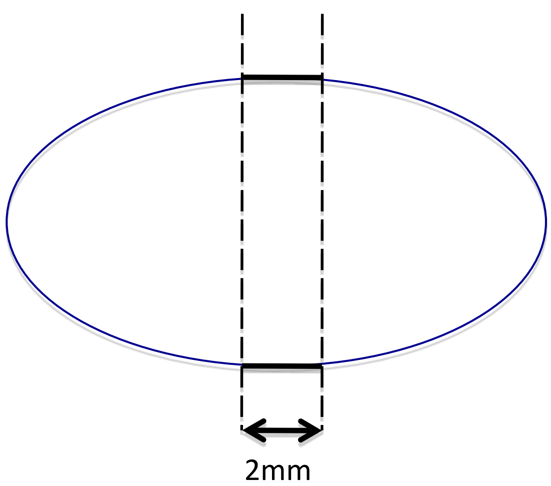
K. Cornelis, S. Cettour-Cave

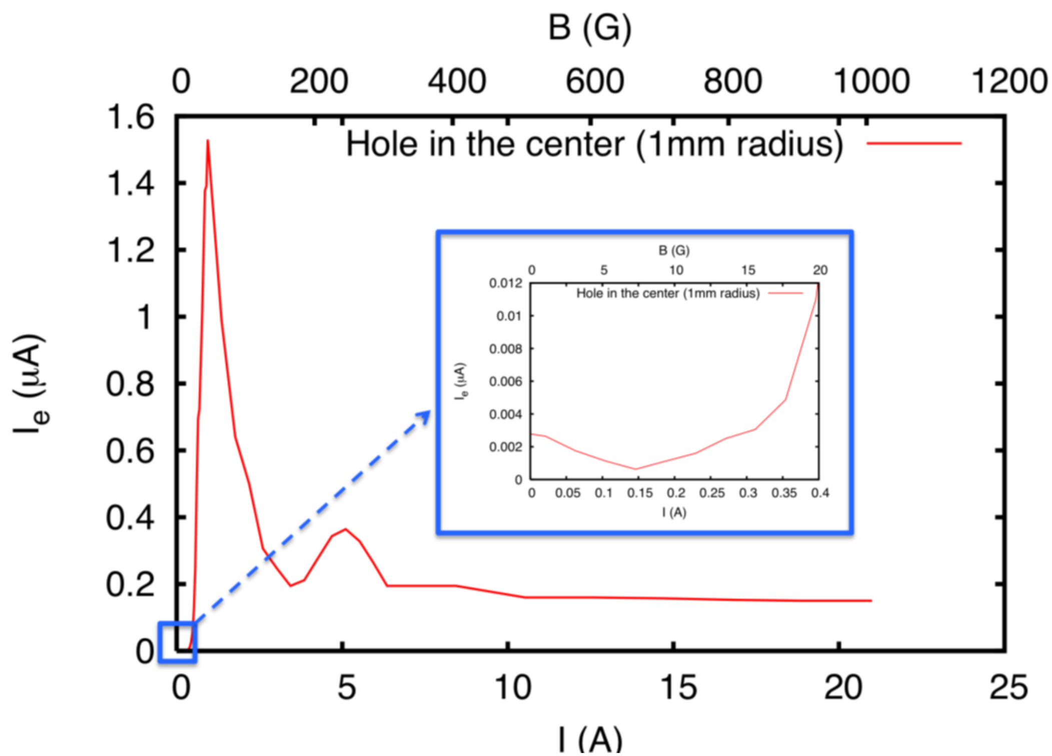
E-cloud simulations with hole

- The **ECLOUD** code had to be modified to take into account the presence of holes in the vacuum chamber walls:
  - ⇒ The charges of the macroelectrons that hit the chamber wall at some predefined hole location(s) are set to zero
  - ⇒ At the same time, their original charges are added into a general accumulator variable that counts the total charge going through the hole (proportional to the signal measured by an e-cloud strip monitor)
  - ⇒ The ‘clean’ routine, called at the end of each bunch passage or inter-bunch gap, eliminates then all the macroelectrons having zero charge, making sure that those that went into the hole(s) are not tracked anymore
- Using the modified version of the code, we simulated the electron cloud build up for MBB dipole chamber geometries with and without holes (exploring a few locations and sizes of the holes) and for a wide range of magnetic field values, compatible with the variation range of the magnetic field in the liners.
- The beam energy is 26 GeV/c and the passage of 4 batches was simulated for each case. The value of the maximum SEY was always set to 1.6 (as expected for StSt after some scrubbing)

E-cloud simulations with hole: one hole in the center of the chamber (1mm radius)

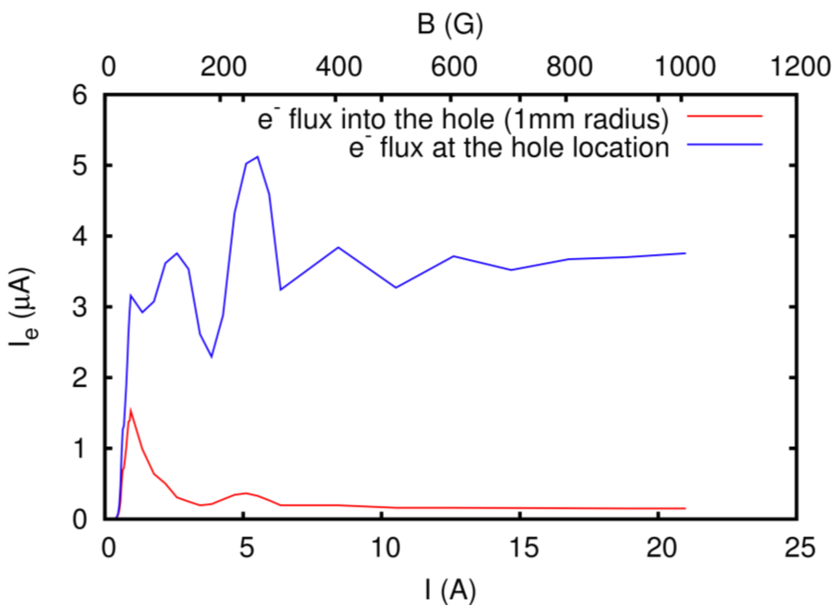
- The measured electron cloud signal, i.e. the total charge into the hole, is a strong function of the magnetic field (on the lower x-axis we have used the current feeding the liner magnet)
- Since the total charge is calculated for 4 batches, the total electron current through the hole, I_e, is obtained by dividing the total charge from the simulation by the revolution period of the SPS.

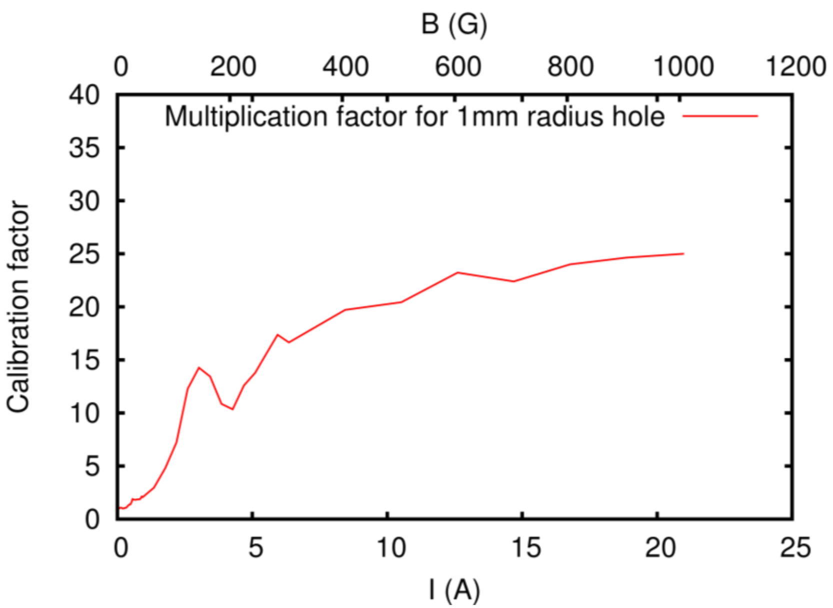


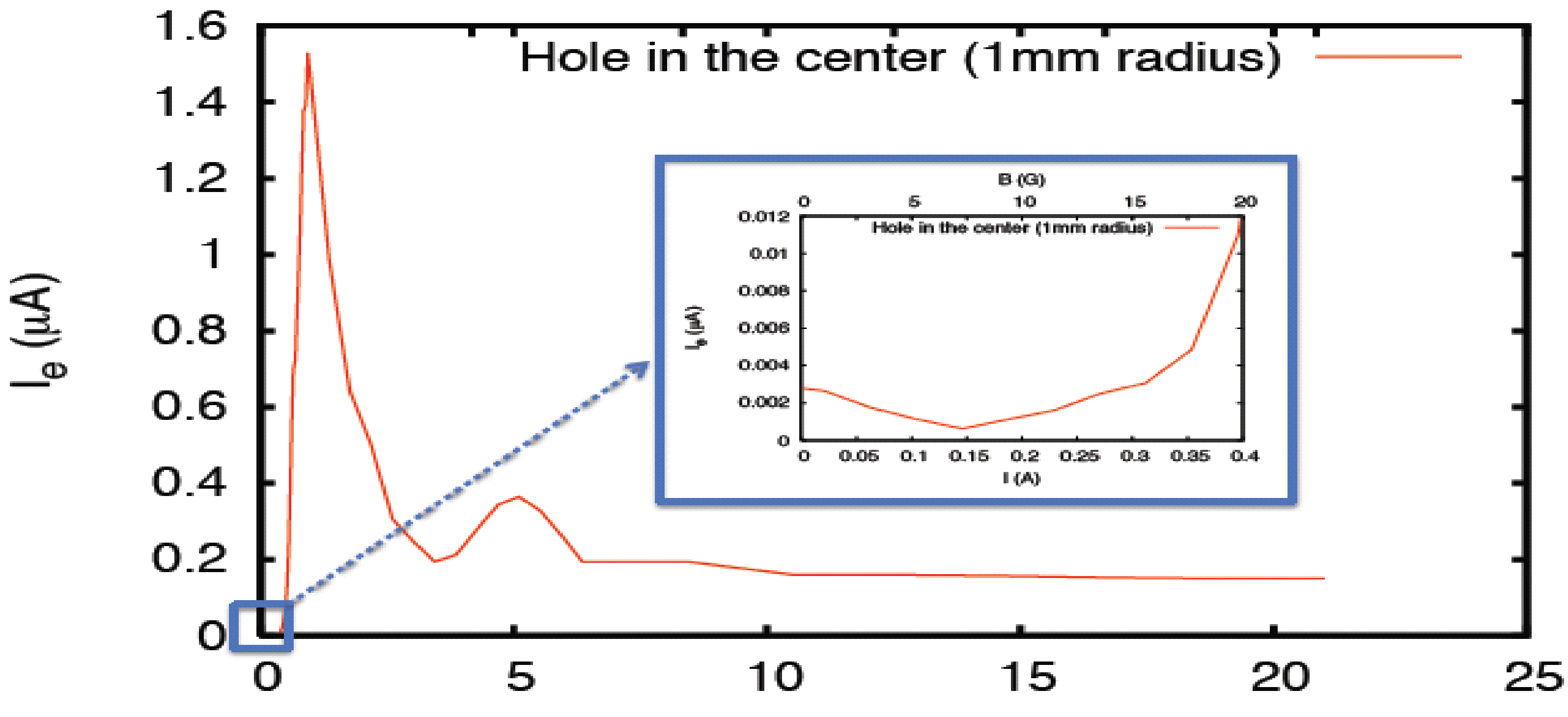


E-cloud simulations with hole: one hole in the center of the chamber (1mm radius)

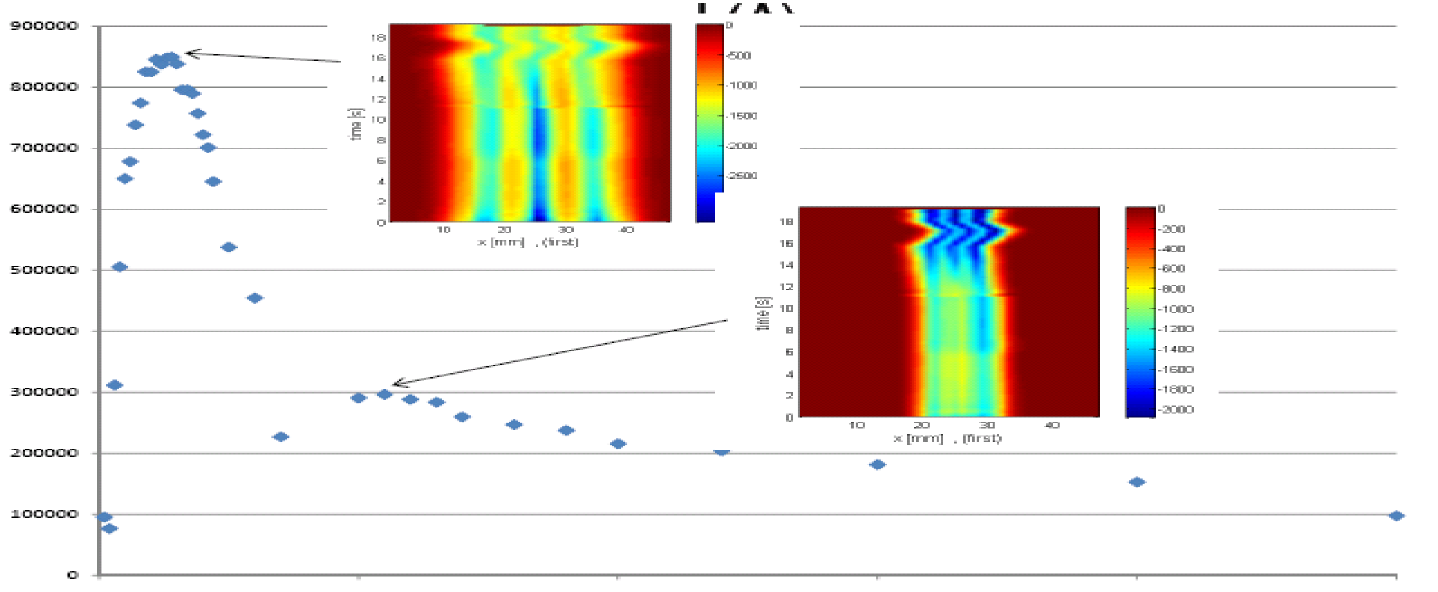
- The fact that the electron current decreases at high values of B is mainly due to local suppression of the e-cloud at the hole location.
- Simulations done without the hole, but counting the total charge hitting the chamber wall at the "virtual" hole location, clearly show this effect (blue curve, plot on the left)
- On the right, we also plot the dependence on energy of the ratio between the unperturbed electron flux at the hole location and the real electron flux into the hole







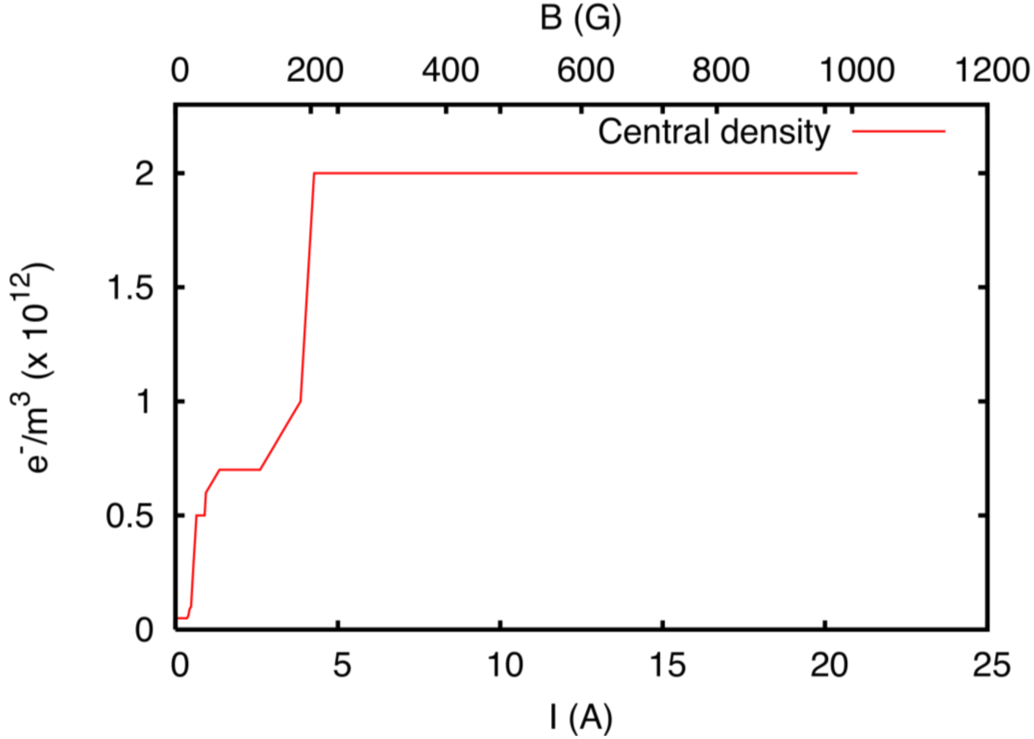
Hole in the center (1mm radius)
Ie (μA)
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
5
10
15
20
25
B (G)
Hole in the center (1mm radius)
Ie (μA)
0.012
0.01
0.008
0.006
0.004
0.002
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
I (A)



900000
800000
700000
600000
500000
400000
300000
200000
100000
0
0
5
10
15
20
25
time [s]
x [mm] , (first)

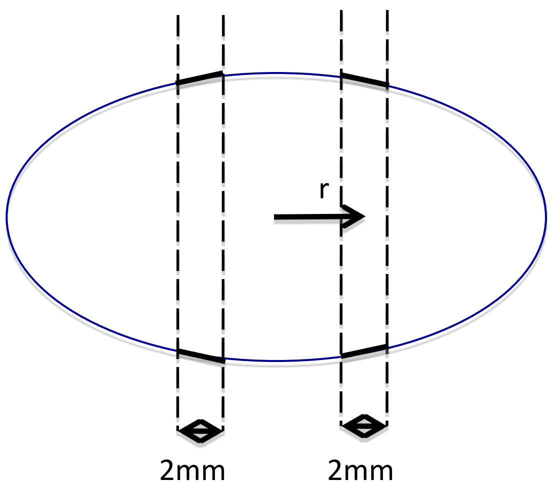
E-cloud simulations with hole: one hole in the center of the chamber (1mm radius)

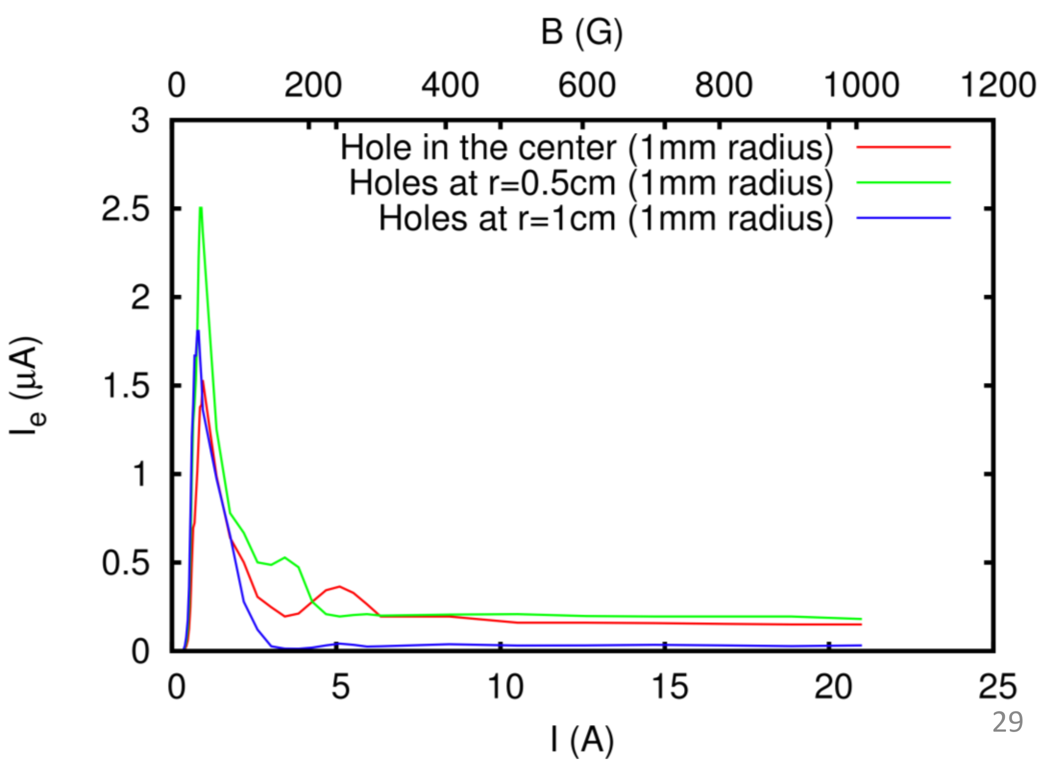
- In spite of the shape of the curve of the measured electron flux into the hole as a function of the magnetic field, the central electron density (which determines the beam stability) becomes higher for strong dipole fields and levels off for B>200G



E-cloud simulations with hole: comparing one hole in the center of the chamber (1mm) with two holes at ±0.5cm and ±1cm

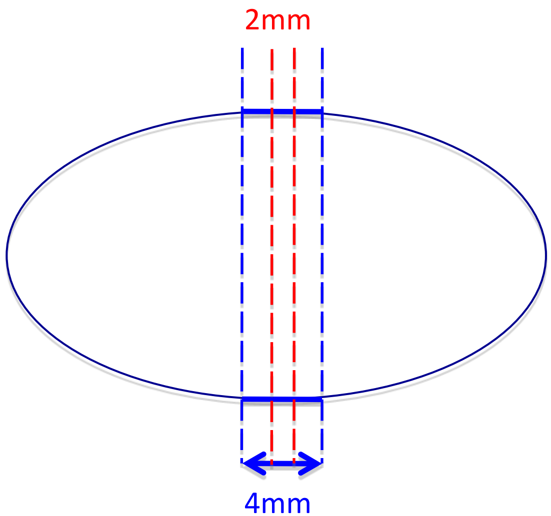
- The average current into the hole has been simulated for the case of central hole (1mm) and for two symmetric holes with respect to the chamber center, located at r=±0.5cm and r=±1cm.
- While the peak at very low magnetic field (~1A) does not change much, the location of the second peak decreases for r=±0.5cm and eventually the second peak disappears for r=±1cm
- The signal for high B values vanishes when the holes are located at r=±1cm

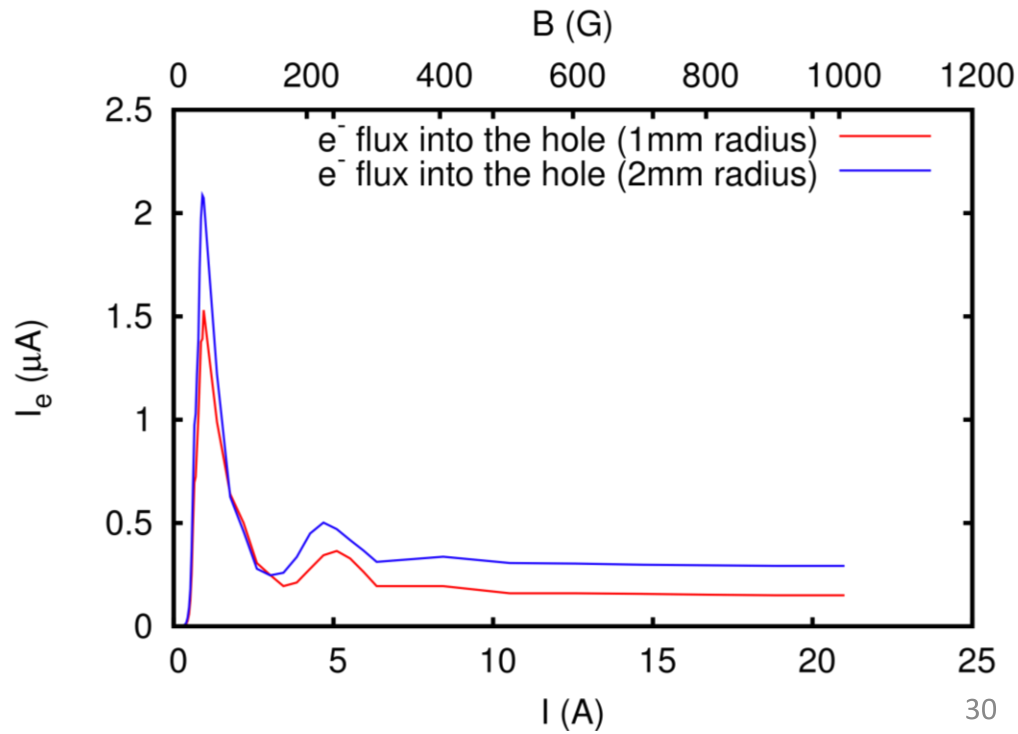




E-cloud simulations with hole: comparing two different sizes of the hole in the center of the chamber (1mm and 2mm)

- The size of the hole does not seem to significantly affect the dependence of the electron cloud signal on the intensity of the magnetic field. This is probably due to the fact that we are considering hole sizes in the same order of the beam transverse sizes. Maybe simulations at 450 GeV/c could highlight a difference between these two cases





Conclusions and outlook

- The presence of holes in the pipe wall can locally affect the electron cloud build up, especially for strong magnetic field perpendicular to the holes. This causes the signal measured by a strip monitor to have different calibration factors according to the magnetic field.
- Following the discussions at the SPSU Study Team Meeting (08.09.2009):
  - The situation when the hole is on one side alone of the chamber should be studied
  - Even better, an array of holes on one side, similar to the real structure of a strip monitor, could be implemented into ECLOUD and simulated
  - However, the strip monitor can only be simulated in 2D, and the incline of the hole arrays over the length of the monitor cannot be taken into consideration in the simulations