topical workshop on

Anti e-Cloud Coatings "AEC'09"

http://indico.cern.ch/conferenceDisplay.py?confId=62873

organized by EuCARD-AccNet-EuroLumi

http://eucard.web.cern.ch/EuCARD/index.html

http://accnet.lal.in2p3.fr/

and SPS Upgrade Study Team

http://paf-spsu.web.cern.ch/paf-spsu/

Summary, by M.Taborelli (CERN-TE-VSC)

TiN
SNS findings (M.Plum, Oak Ridge), TiN in J-Parc (S.Kato), TiN at KEK (Shibata), TiN in CESR-TA (M.Palmer, Cornell), TiN at SLAC(M.Pivi)

Carbon coatings
Characterization (M.Taborelli, CERN), SPS e-cloud CESR-TA(C.Yin-Vallgren, CERN), SPS pressure (M.Taborelli, CERN), SPS dipole coating, technique (P.Costa Pinto,CERN), SPS coating, strategy for the entire machine (J.Bauche, CERN), Impedance (D.Seebacher,CERN), Microwave diagnostics (F.Caspers, CERN), DLC (S.Kato, KEK)

Low SEY by rough surfaces and grooves
Rough surfaces (I.Montero, CSIC Madrid)
Grooves (M.Pivi), Grooves with TiN (M.Palmer, Cornell)

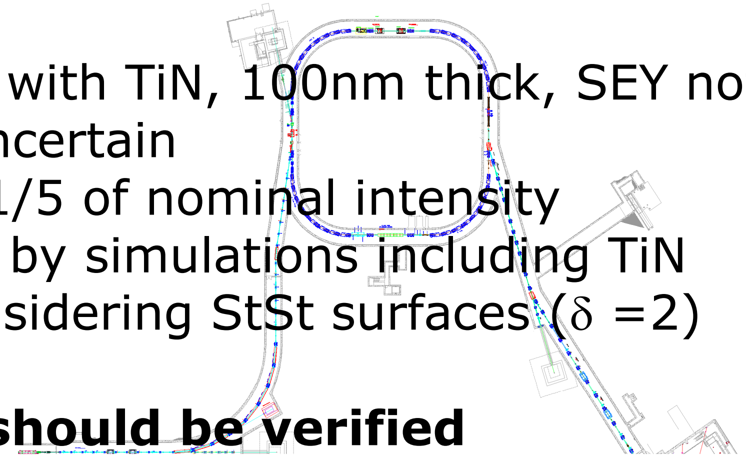
Clearing electrodes (E.Mahner, CERN)

Simulations: SPS situation (G.Rumolo CERN), CESR-TA situation (J.Crittenden, Cornell)

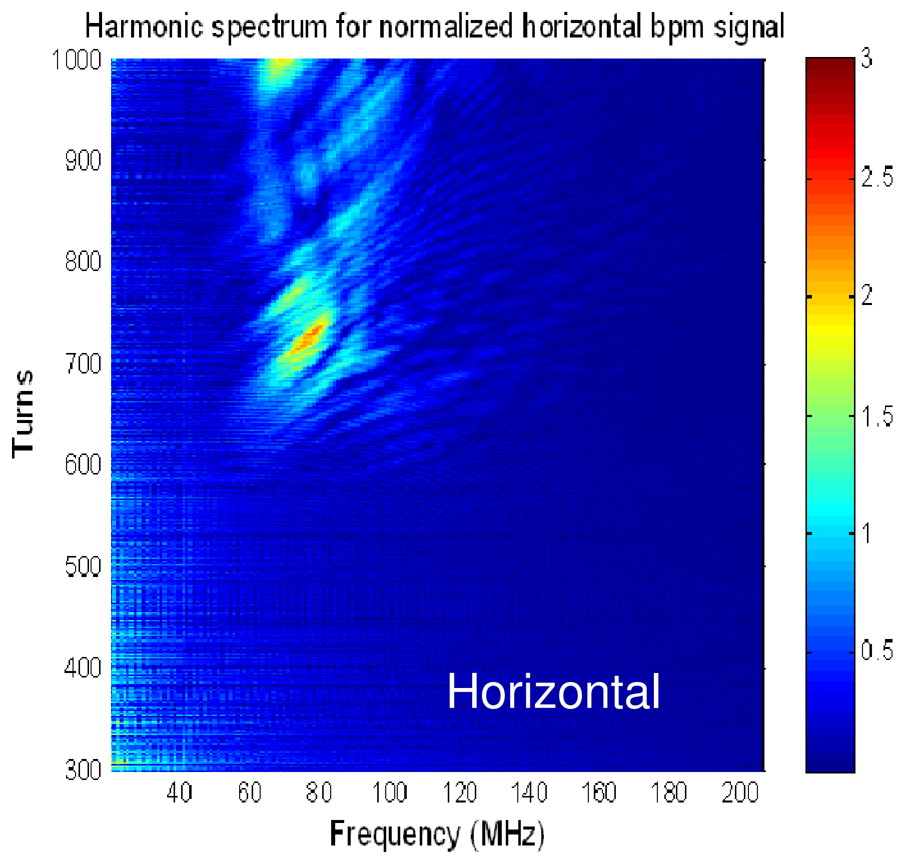
My comments are in red
…and I tried to be honest!

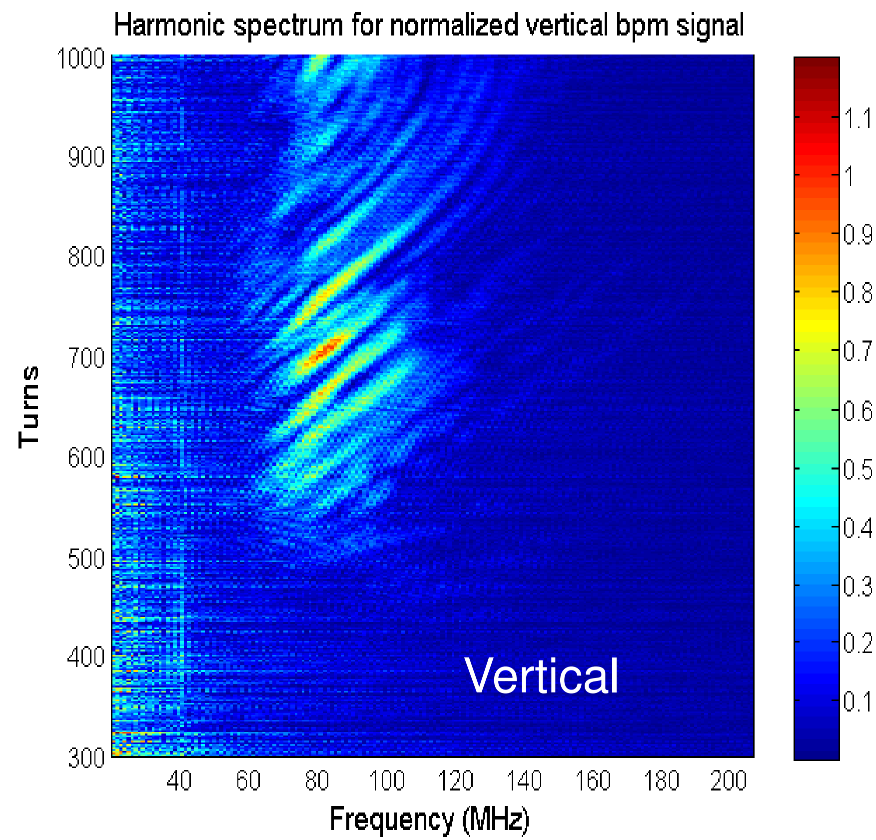
TiN coatings

SNS (M.Plum, Oak Ridge): protons



- -95% of the accumulator ring is coated with TiN, 100nm thick, SEY not measured, conditioning state uncertain
- -there is **e-p instability** in the ring at 1/5 of nominal intensity (3E13p/b), it was not predicted by simulations including TiN coating as well as for those considering StSt surfaces ($\delta = 2$)
- -Ring-RF can control the instability
- **-is TiN really useful? Effectiveness should be verified**

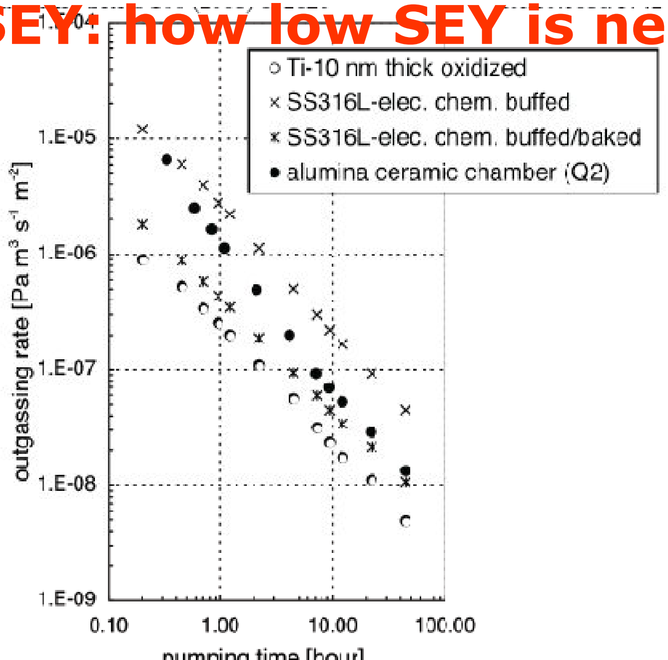




TiN in J-Parc (S.Kato, KEK): protons

- -on **alumina chambers** used in RCS (rapid cycling synchrotron) magnets (200m coated chambers on 350m machine), 15 nm thick coating, by hollow cathode technique
- -**no problems after 1 year of operation**, however at very low beam intensity, **not in e-cloud conditions**
- -no evidence of e-cloud in the ring (pressure monitoring)
- -very low static degassing (better than unbaked StSt)
- -no direct measurement of SEY, guess 0.8-1.1 after conditioning

Probably on alumina almost everything would lower the SEY: how low SEY is needed?



3. Outgassing rate of the alumina ceramic chamber for the quadrupole magnet.

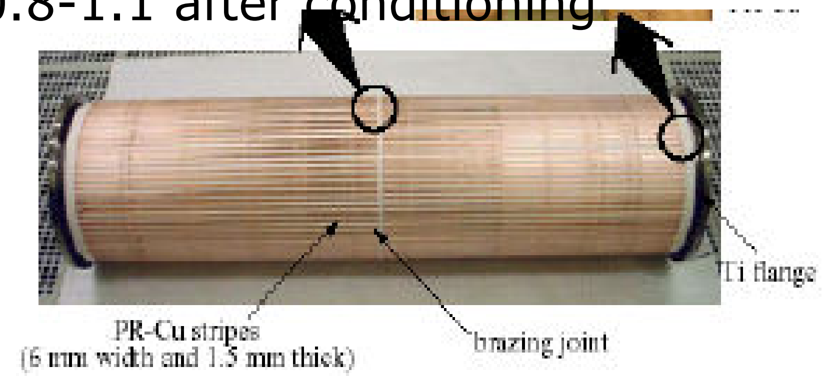


Figure 5: Ceramics chamber of quadrupole

TiN in CESR-TA (M.Palmer, Cornell): e+,e-

RFA signal (e-cloud) in drift space: photons from dipole!
-TiN as Cu, for e+ beam (where also e-cloud is expected)
-**TiN better than Cu for e- beam** (where no e-cloud is expected and the signal is dominated by **photoelectrons**)
-conditioned

TiN seems good with photons (low photoyield?)

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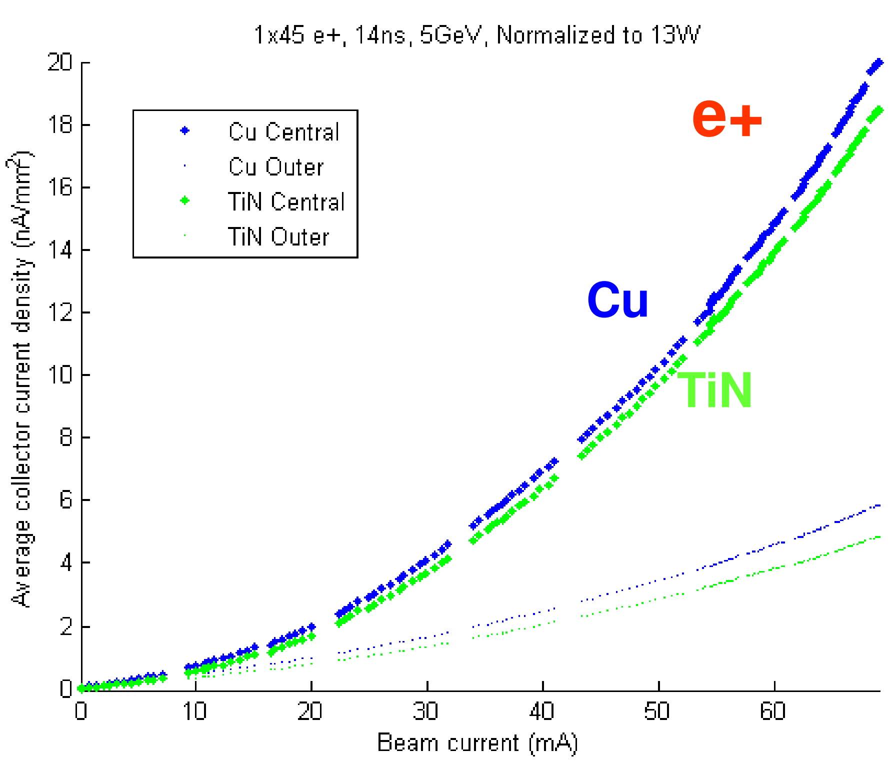
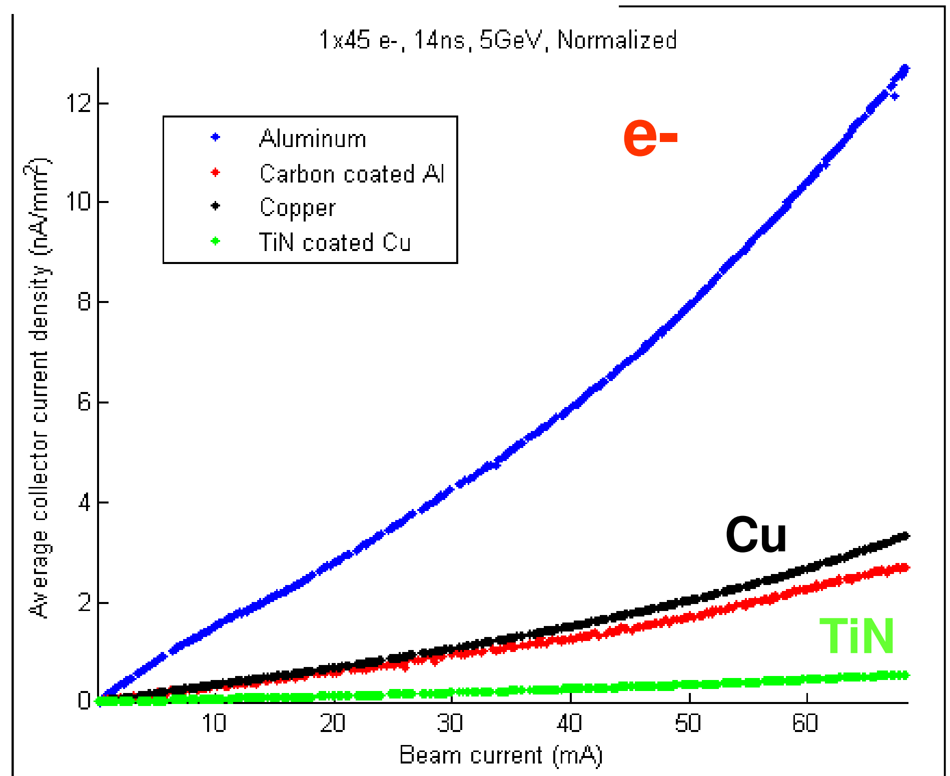
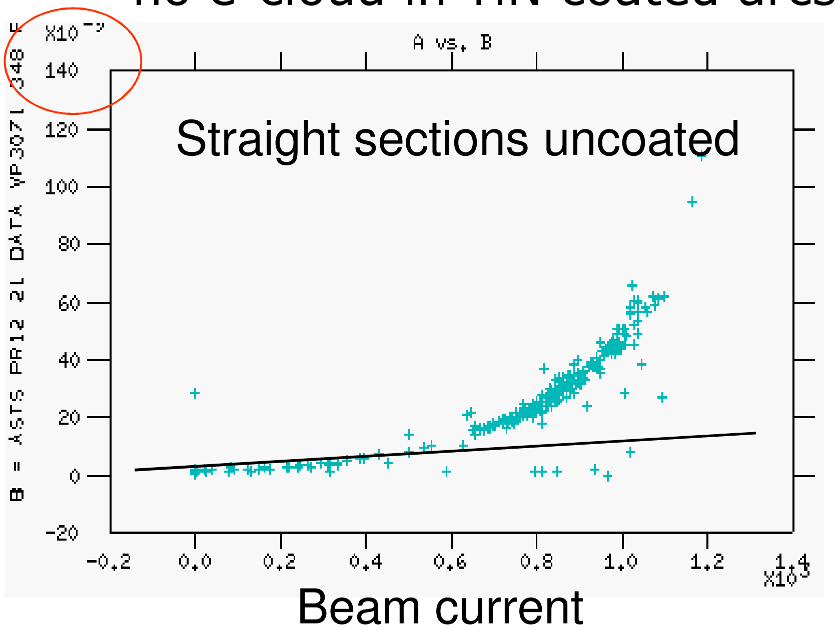
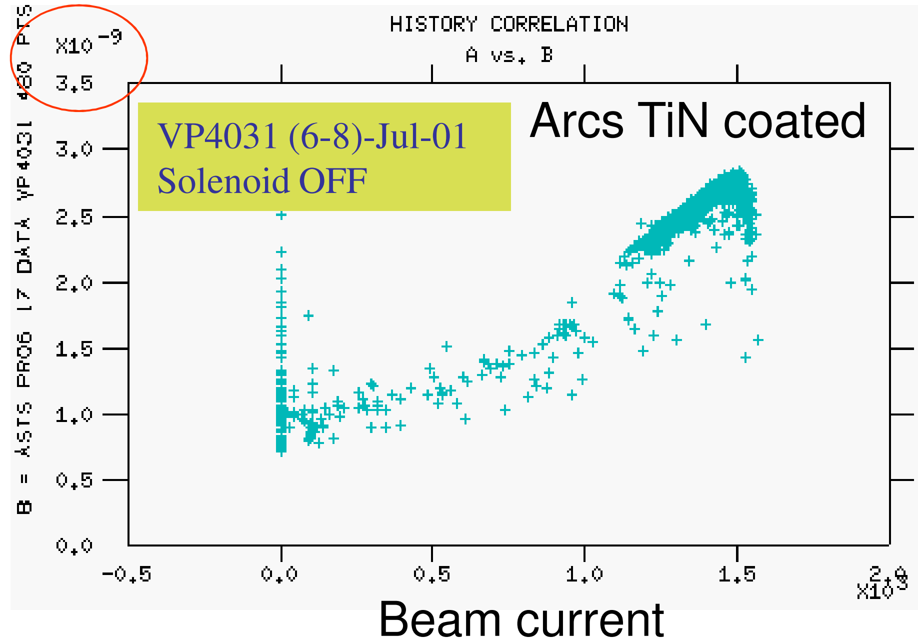




TiN in PEPII-LER (M.Pivi, SLAC): e+

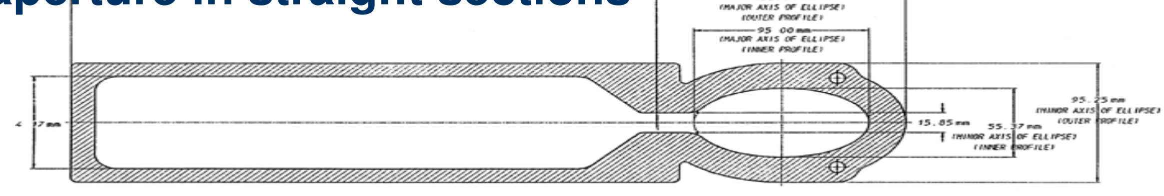
-e-cloud in uncoated StSt straight sections (pressure rise)
-no e-cloud in TiN coated arcs





PEP-II reached 3 x Design Peak Luminosity. Presumably TiN coating and antechamber in arcs played a big role (!)
No direct data about TiN coated vs un-coated, since no electron detectors were installed at the time yet, i.e. 2003.

Note also larger chamber aperture in straight sections



Removable samples exposed to the beam environment and measured in the lab after conditioning by the PEPII beam:

- TiN best performances, measured SEY < 1,
  - Carbon and Oxygen content <u>decreased</u>
  - Kept in stand-by in vacuum: SEY<1 even after 1000 hours (!)
- Aluminum conditioned but still SEY > 2!

Conditioning through photons (and ions? how much?). Note that conditioning with e-beam in the lab gives increasing C (S.Kato)

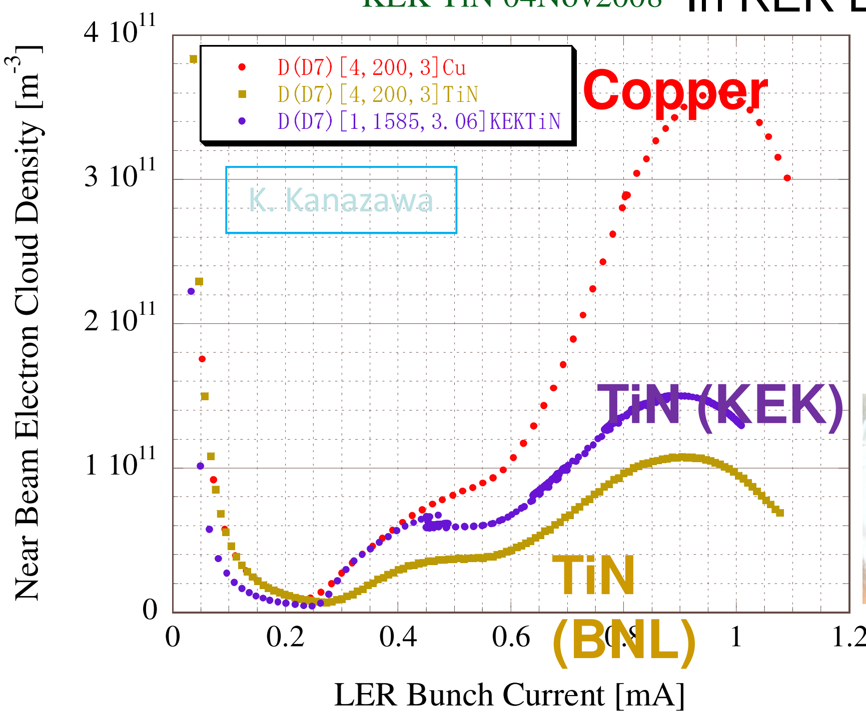
K.Shibata (KEK): LER (Super)KEKB, e+

-Producing TiN/Cu: best samples for adhesion on Cu and low SEY (δmax= 1.2 at 1E-5C/mm^2) on 150C substrate

-Unbaked coated pipe has 5 times more outgassing than Cu uncoated pipe, but moderate baking (80-100C) can lower outgassing to the level of uncoated Cu chamber

-lower e-cloud than in uncoated chamber

KEK TiN 04Nov2008 In KEK LER



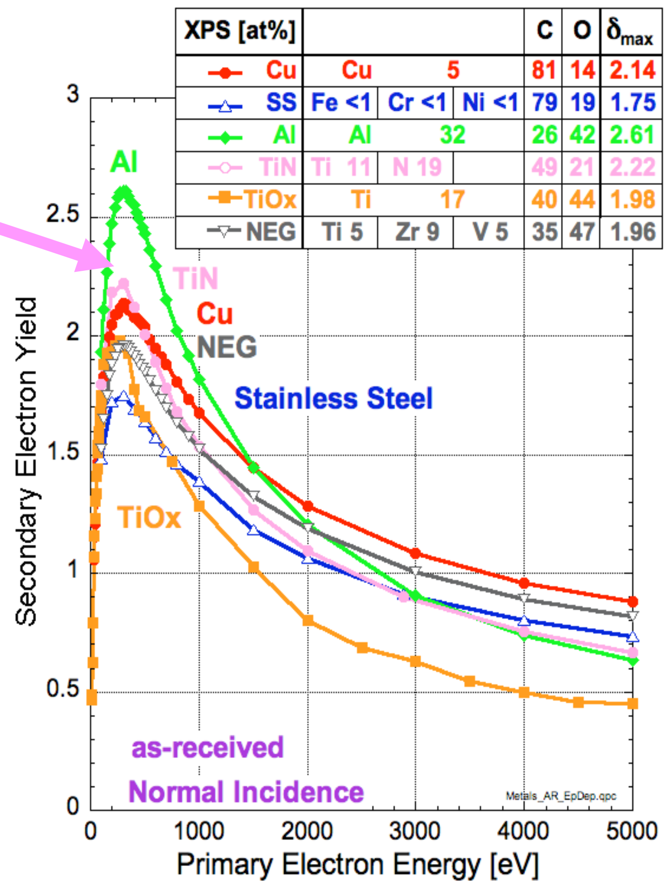
Again TiN is good with photons!
In conditioned state

TiN-coated duct (ϕ94 mm)

In the following autumn run, Al ducts and groove surfaces (Al and Cu) with and without the TiN coating will be tested in KEKB LER

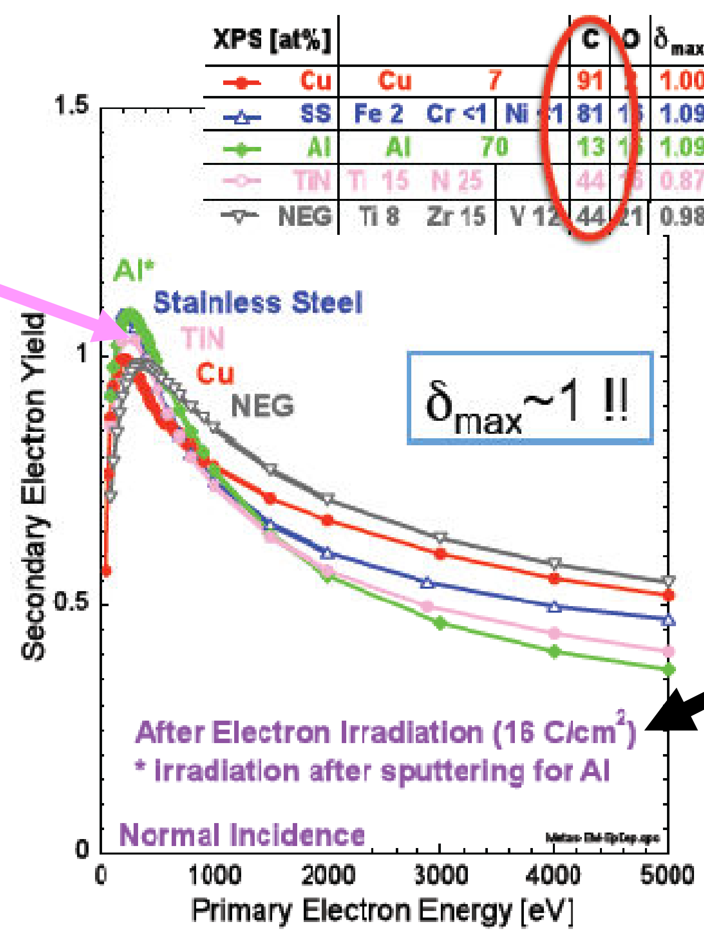
TiN measurements in the lab: (S.Kato, KEK)

As received state



XPS [at%]				C	O	δ_{max}
Cu	Cu 5			81	14	2.14
SS	Fe <1	Cr <1	Ni <1	79	19	1.75
Al	Al 32			26	42	2.61
TiN	Ti 11	N 19		49	21	2.22
TiOx	Ti 17			40	44	1.98
NEG	Ti 5	Zr 9	V 5	35	47	1.96

Electron Irradiated Metals



XPS [at%]				C	O	δ_{max}
Cu	Cu 7			91	[illegible]	1.00
SS	Fe 2	Cr <1	Ni <1	81	[illegible]	1.09
Al	Al 70			13	[illegible]	1.09
TiN	Ti 15	N 25		44	[illegible]	0.87
NEG	Ti 8	Zr 15	V 12	44	21	0.98

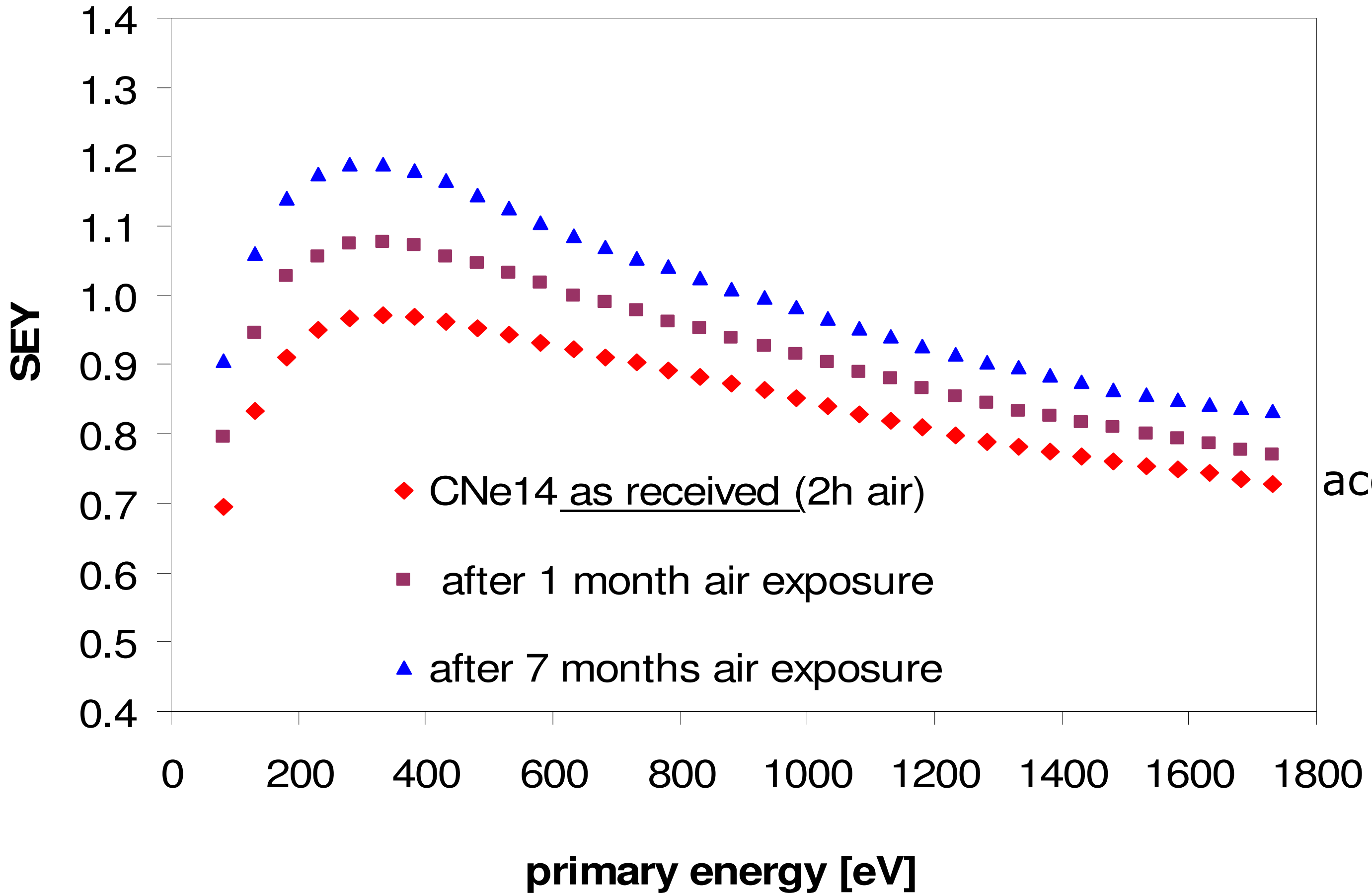
Dose of irradiation in the lab at 5KeV electrons

Data consistent with other labs (CERN, SLAC)

After a strong conditioning by an e-beam almost everything is good

SEY of carbon a-C coatings (M.Taborelli)

C coatings

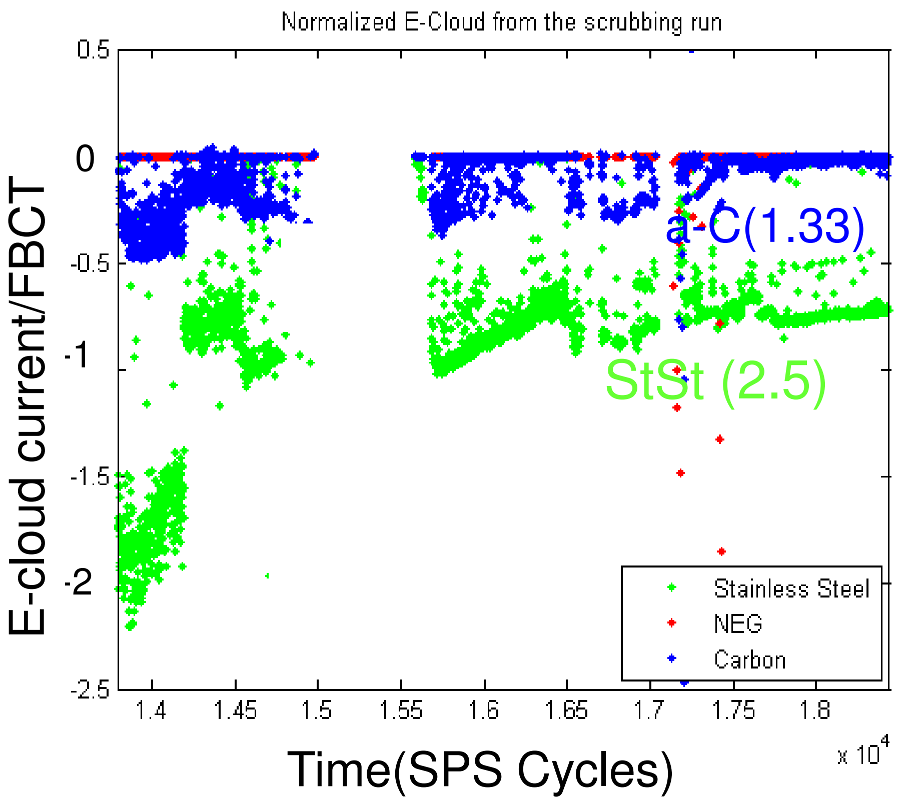


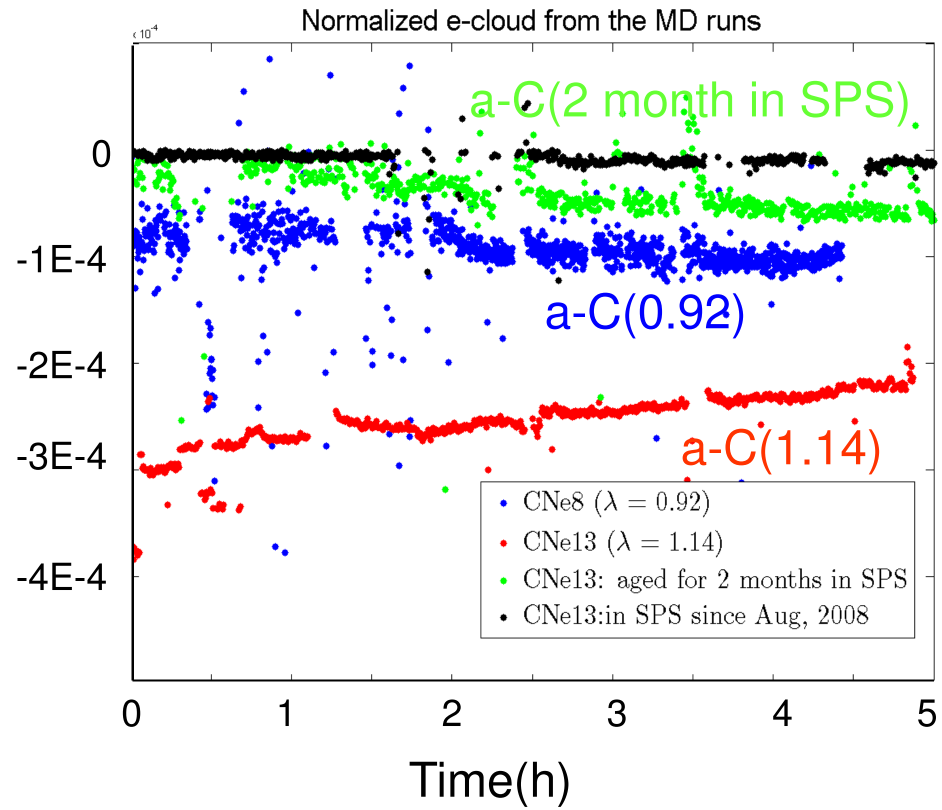
accuracy +/-0.03

-no bake-out
-as expected SEY does not change for thicknesses above 50 nm
-scattering in production 0.9< δmax <1.1
-aging is moderate in N2, dessicator or wrapped in Al foil
-partial recovery possible by heating (200C) or plasma cleaning

a-C coatings results from e-cloud monitors in SPS (C.Yin-Vallgren)

LHC type beam at 25ns spacing, 72 bunches, 1-3 batches
Strong reduction of e-cloud current



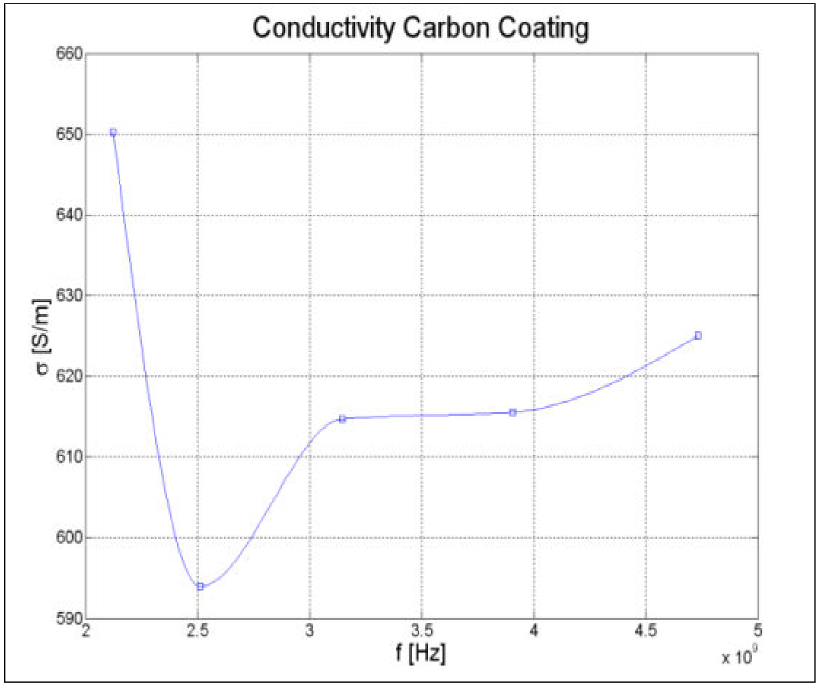


Impedance of the coatings (D.Seebacher)

- Cavity perturbation (detuning) method was used to measure the properties (2-4GHz range)
- Coatings of NEG and a-C of different thickness on glass rods, inserted in the cavity

- NEG shows resistive behaviour (metallic conductor); conductivity is too high to be measured
- a-C shows the behaviour of a bad conductor (4000S/m, 0.25μmthick, or 1kΩ square) **with no effect of dielectric constant**

Strange behaviour as a function of frequency: the rod is not a small perturbation!



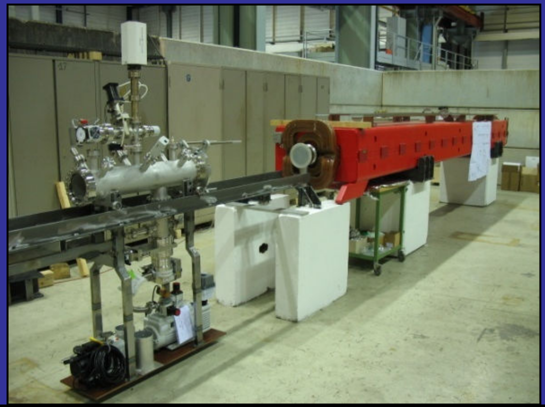
C coatings

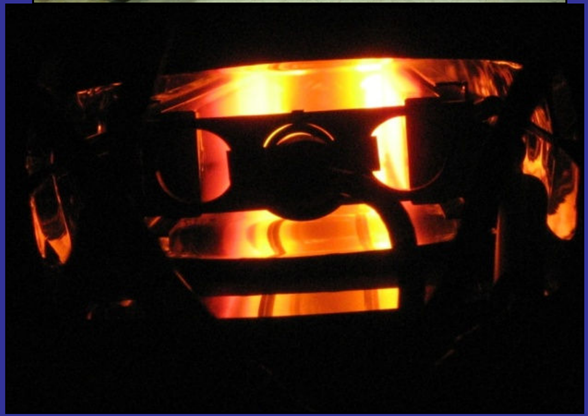
Coating of 3 MMB dipoles for SPS tests (P.Costa Pinto)

DESIGN and BUILT-UP

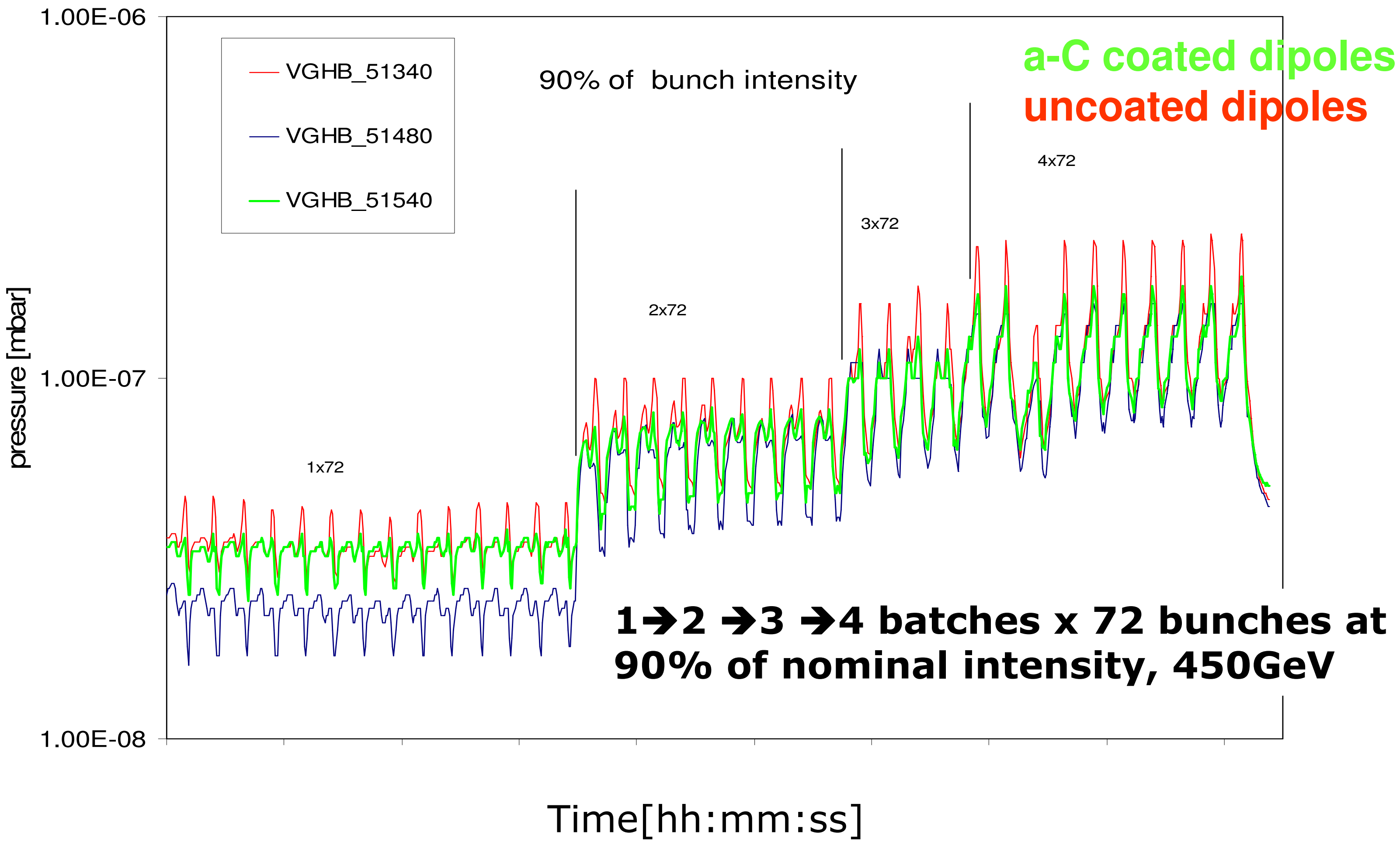
January 2009: arrival of first pieces: assemble vacuum and bench.

February 2009: adapt electrodes. Start tests and coatings.
March 2009: insertion in SPS





Pressure measurements in SPS (M.Taborelli)

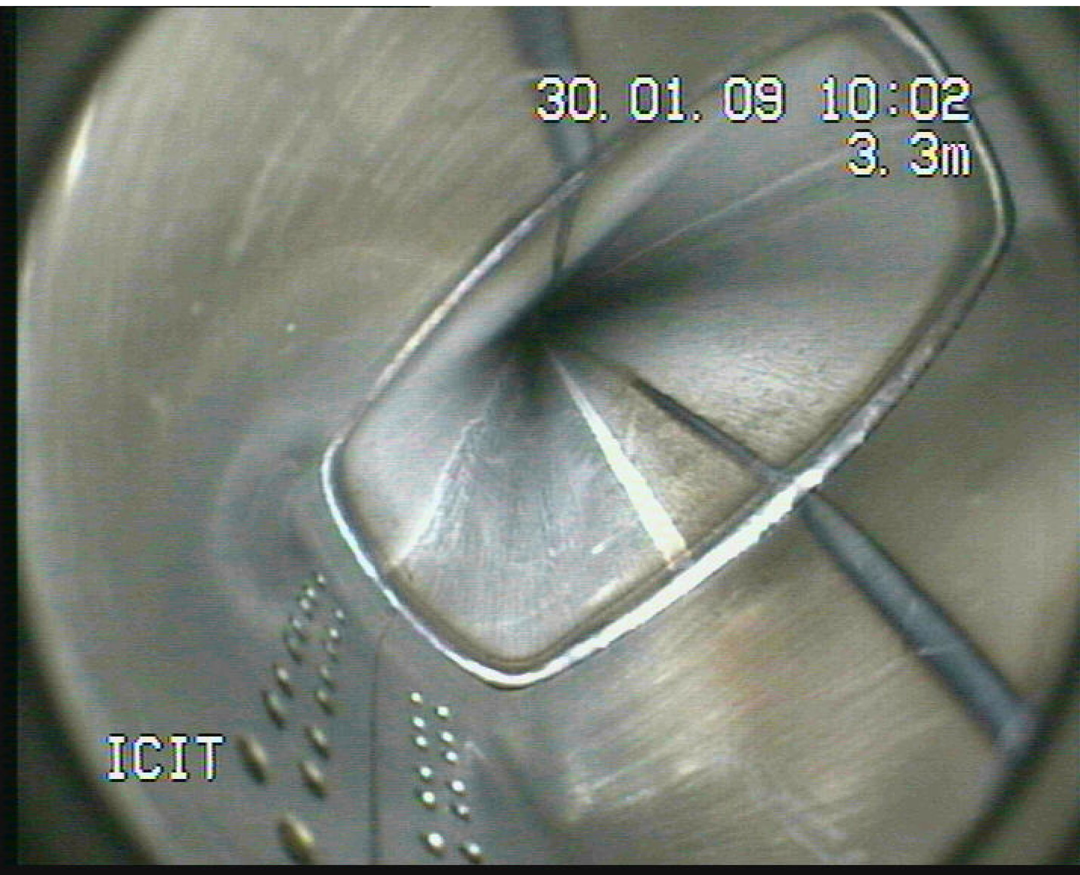


Pressure rise is stronger between 1st and 2nd; coated magnets are only slightly better for higher number of batches. Less improvement than expected.

C coatings

E-cloud in uncoated areas

E-cloud occurs in these areas too!
The RF-shields show discoloration lines (inspection 6/10/2009)



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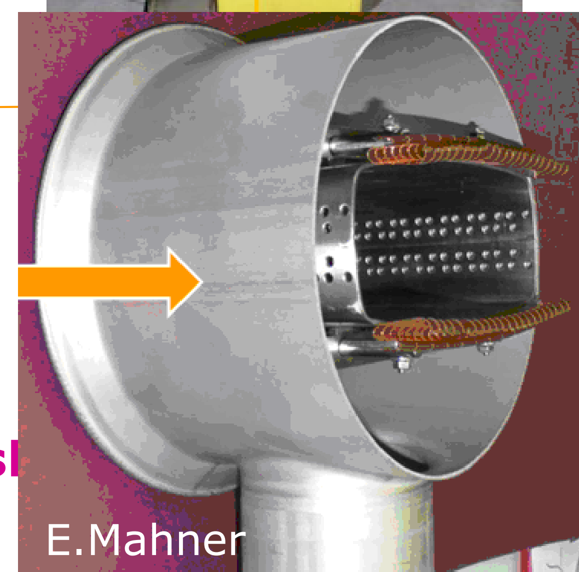


C coatings

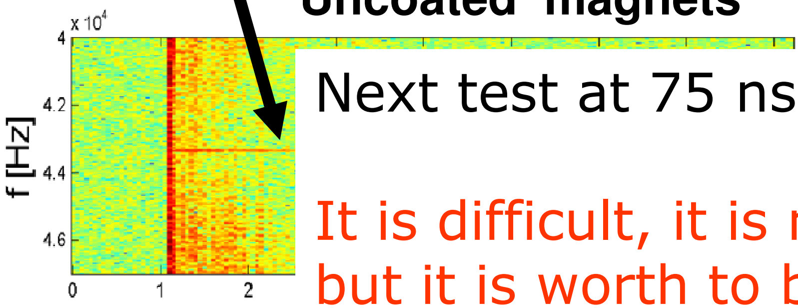
Diagnostic of Coating Results: Microwave Measurements

S. Federmann

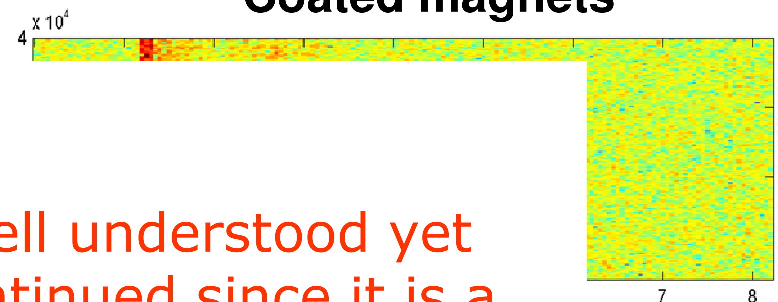
- Measurement of phase modulation of a microwave (MW) signal due to ecloud, in principle sensitive to the e-cloud density where it travels

Beam 1 batch, 72 bunches:
PM signal in uncoated magnet 10 dB above noise

Uncoated magnets



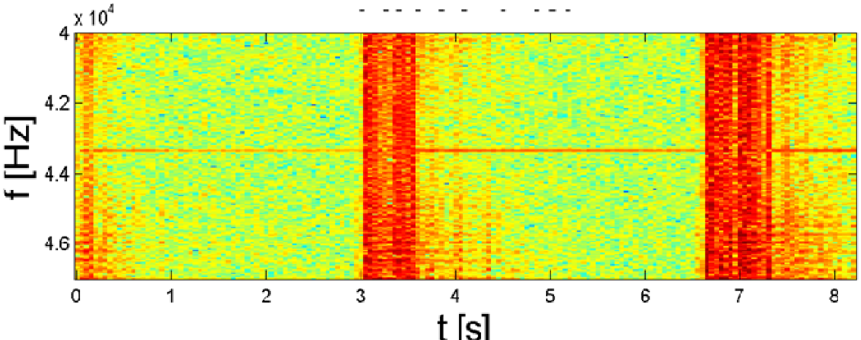
Coated magnets

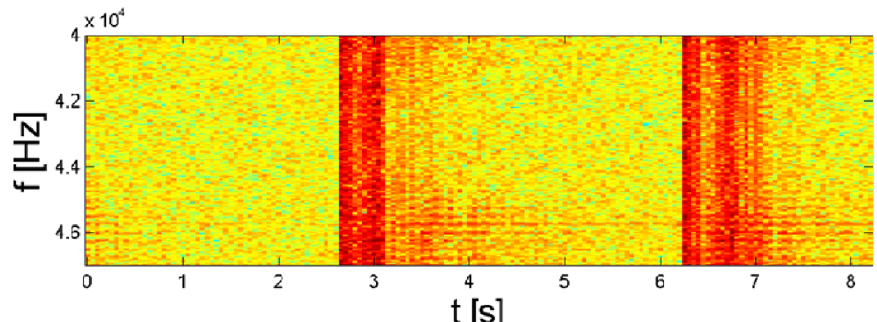


Next test at 75 ns

It is difficult, it is not well understood yet but it is worth to be continued since it is a direct measurement of what happens in the dipoles!

1-2-3 batches





Comparison Al, a-C/Al, Cu, TiN/Cu at CESRTA (S.Calatroni)

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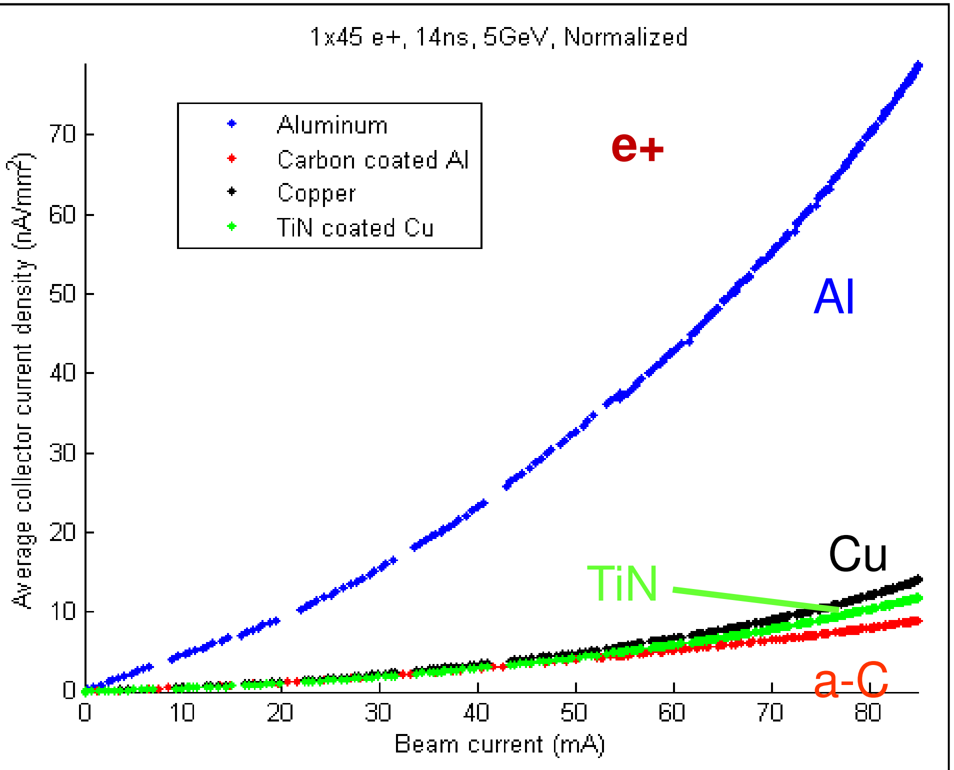
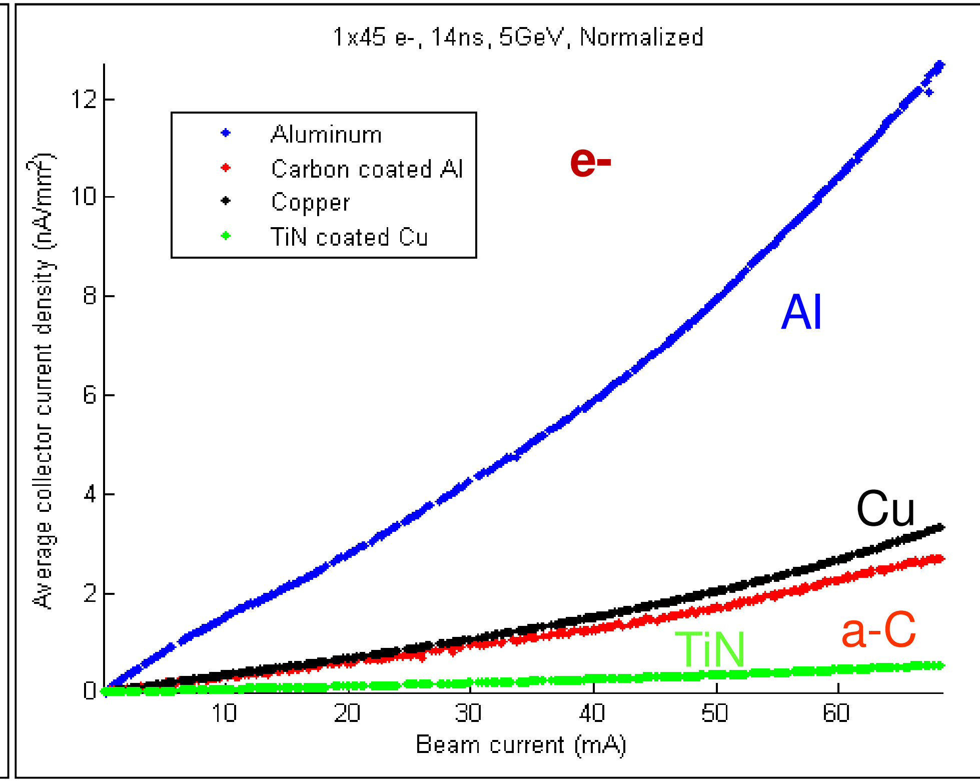
CESR-TA results on a-C CERN coated chamber: conditioned state



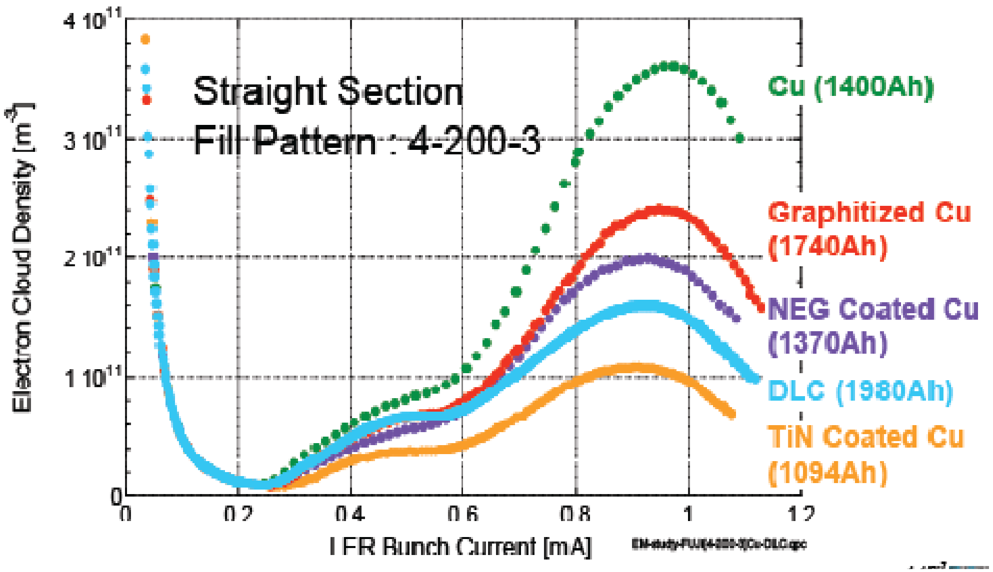


-a-C is much better than bare Al and better Cu for both, e+ and e-
-TiN is better for "only photons", a-C is better when e-cloud might occur
-possible corrections could come from photon flux differences (local machine geometry)
-a-C chamber contaminated with silicone (kapton adhesive tape) during acceptance test

Graphitization and DLC coatings: (S.Kato, KEK)

-Conditioing with e-beam induces an increase of C on the surface and decreases SEY
-Graphitic C…called graphitization: try to do it on the beampipe before insertion by bombarding with electrons from a filament
-Compare with DLC coating (commercial)

KEKB: e-cloud monitor in the machine



-Conditioned state
-Graphitization layer is probably too thin
-DLC is not considered of the best quality which can be achieved: the experiment will be repeated this fall with a better coating

RFA collectors are tricky!

-Transmission should be simulated and taken into account for interpretation of the data: depends on B-field (see e-cloud monitors in SPS), on angle of incidence of the electrons…..

-Energy spectrum of the collected electrons is even very difficult to measure due to secondary electrons generated in the RFA itself and angular effects

-Design of all collectors seen is much more primitive that all what is done in surface science analysis systems, due "accelerator constraints (space, integration in a vacuum chamber, surrounding noise ……)

-Materials used are often at the edge of compatibility with UHV

Logistics for SPS dipole coating campaign: (J.Bauche)

-Three possible strategies

-Cleaning/coating in the SPS tunnel

-Cleaning/coating in ECX5 cavern

-Cleaning/coating on surface

-Obvious differences in radiation levels to cope with, transport (more or less handling is needed, handling of waste……the best solution must still bed ecided by putting everything on the balance

-In all cases 3 shutdown periods are necessary

-All should be in place for 2015 typically

Other projects for coatings against e-cloud:

FNAL (U,Wienands), TiN for upgrade of main injector of project X

The setup will be assembled in the next few weeks (short prototype); needs articulated electrode to coat dipoles (1.5 cm sagitta), by magnetron (SLAC technique)

Coupons will be used to monitor thickness, nominal value is 100 nm

Coating is expected for November.

Coating in situ (A.Herskovitch, BNL) with a mole

RHIC for electrons

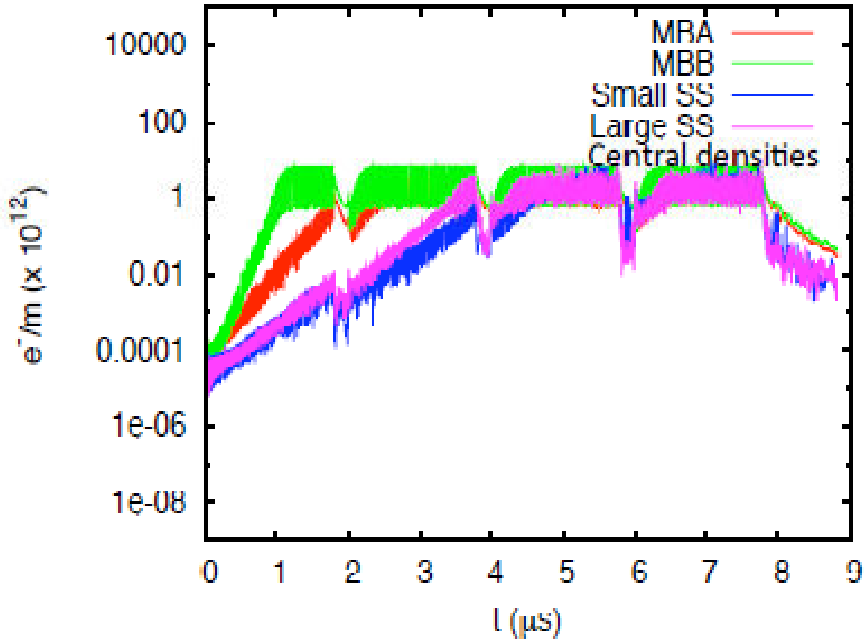
Would like to coat 500m in situ

Very preliminary stage of the study

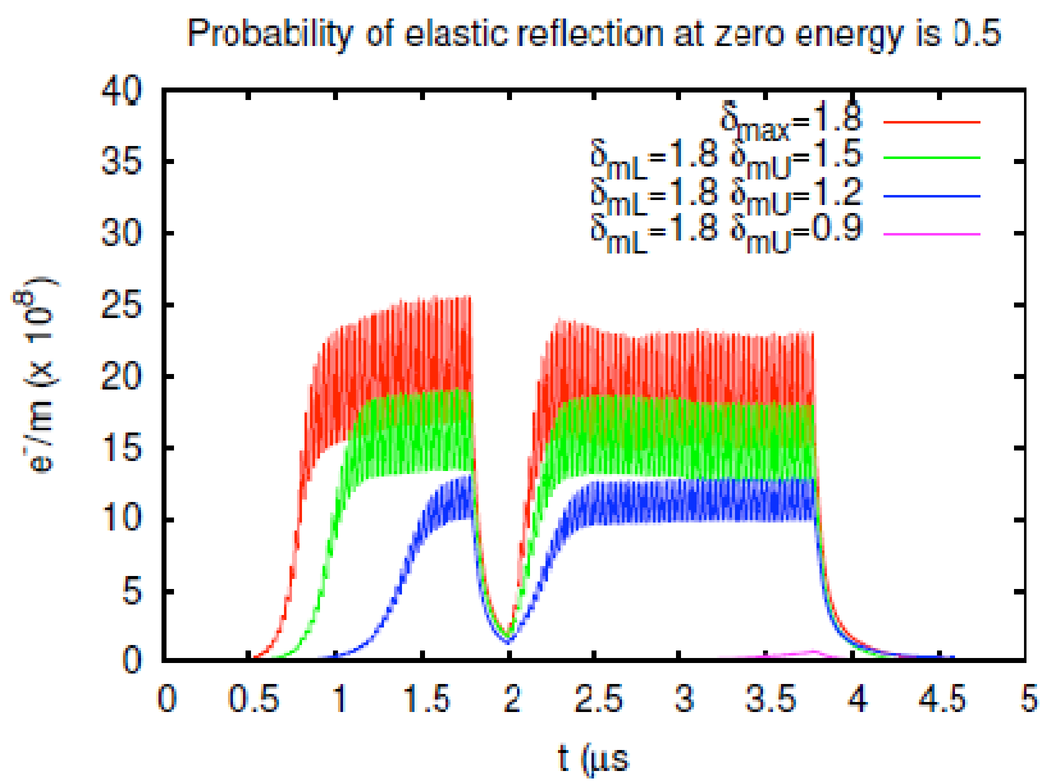
Not decided which coating

ECLOUD simulations (V)
Comparing all types of dipole/SS chambers (G.Rumolo)

- For δ_{max} **below 1.5**, there is **electron cloud only in the MBB's**. (the MBB threshold is $\delta max<1.3$)
- If we assume δ_{max} **of 1.6** (measured value for scrubbed Stainless Steel)
  - ✓ Only MBB dipole chambers would be affected by a strong electron cloud for 1 LHC batch (25ns) circulating in the SPS (including chamber edges with fringe fields)
  - ✓ 2^{nd} to 4^{th} batches are affected by significant electron cloud also in MBA chambers. Only 3^{rd} and 4^{th} batches see strong electron cloud in the SS's.
  - ✓ The values of the central e-cloud densities are the same at saturation ($\approx 2\times10^{12}$ m^{-3})

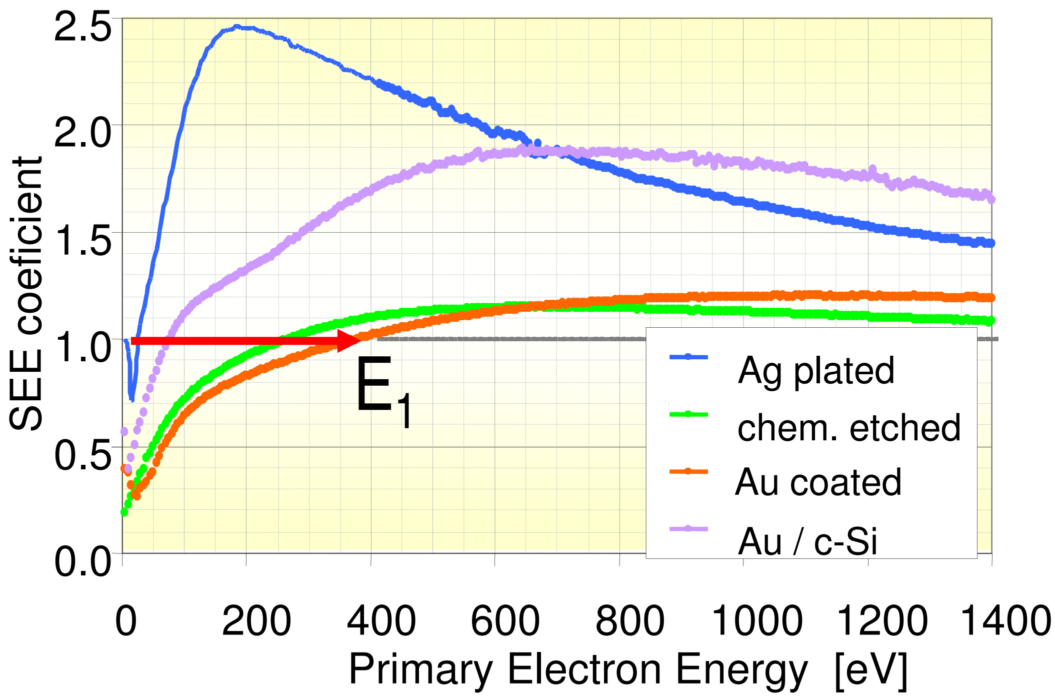


ECLOUD simulations (I)
Applying one-sided coating (G.Rumolo)

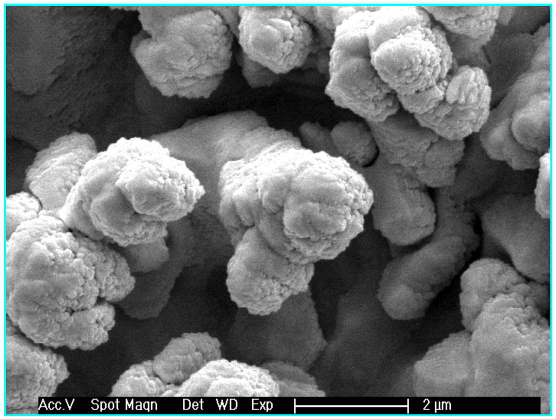


- Maybe we could coat only half of the chamber wall? (P. Costa-Pinto *et al.*)
- With a default δ_{max} of 1.8 on an MBB type chamber wall, coating only the upper (or lower) half of the chamber can decrease the electron cloud, and it almost suppresses it if the δ_{max} of the coated region is below 1.
- In the simulations above it was assumed that the probability of elastic reflection is 0.5 at 0 energy.

Lowering SEY by rough surfaces (I.Montero, CSIC Madrid)



Microstructured Au coating

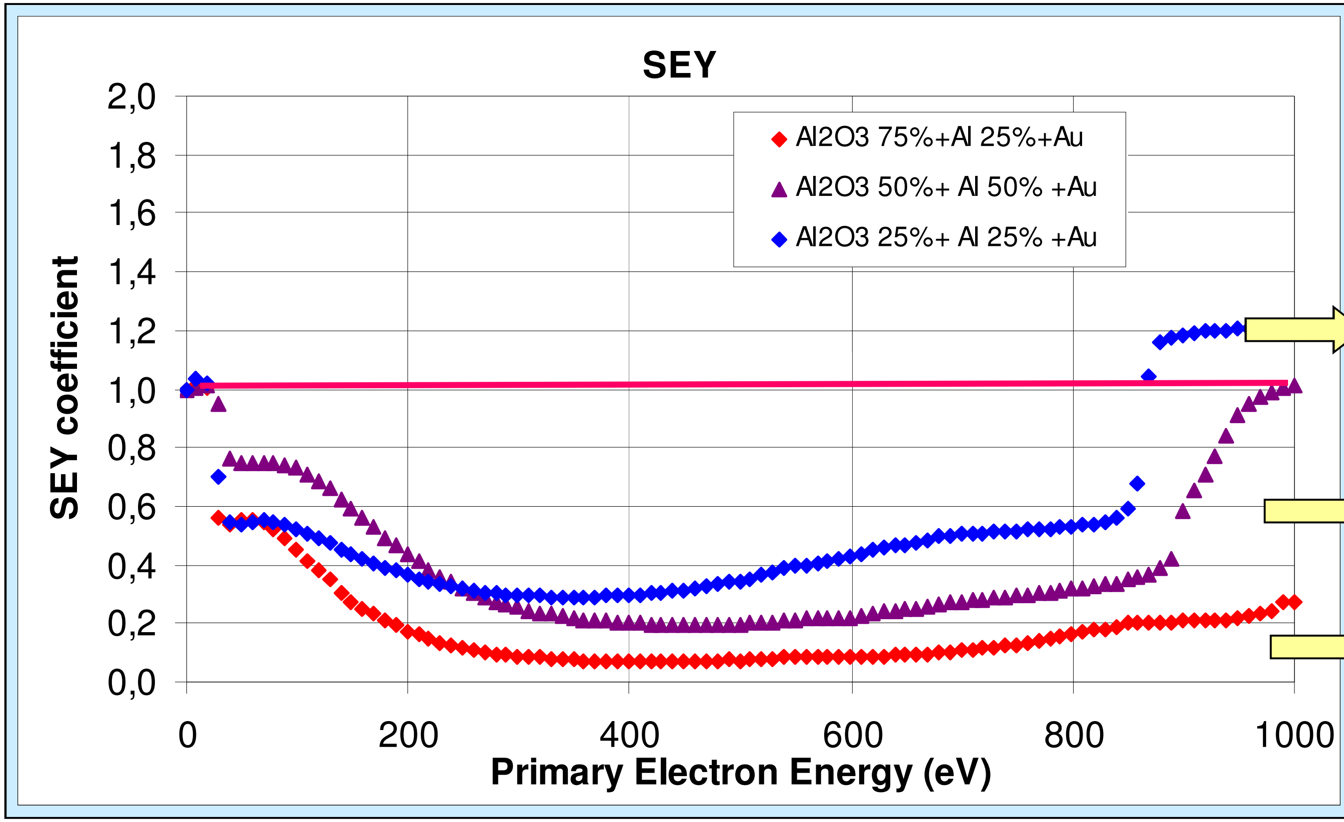


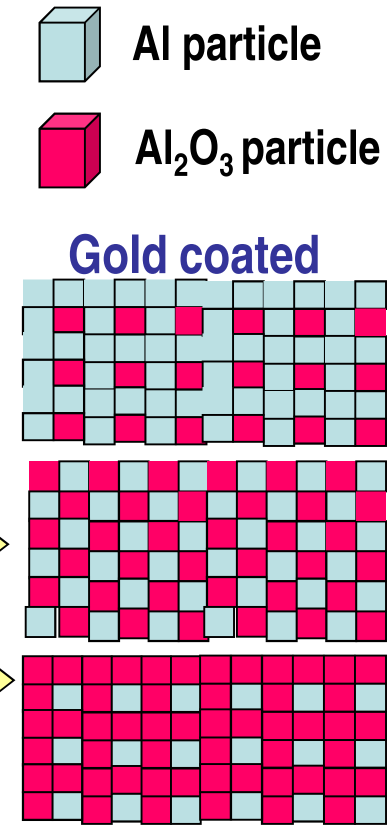
The surface is fragile!

Issues for degassing if it cannot be baked (resistance to temperature treatment not verified)

Metallic/Dielectric Microparticles Coatings

Extreme reduction of SEY



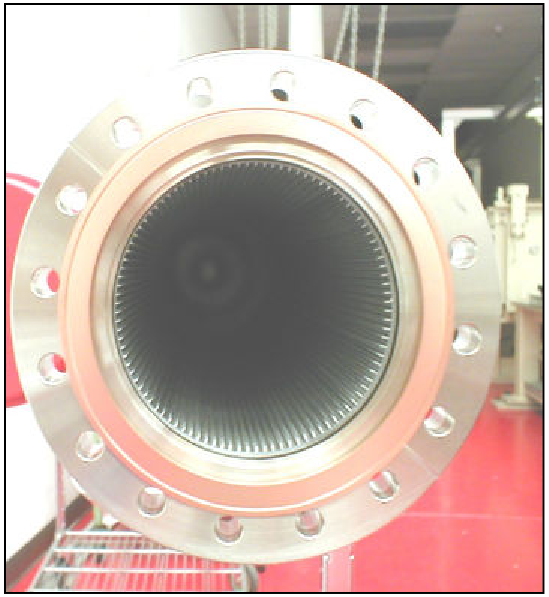


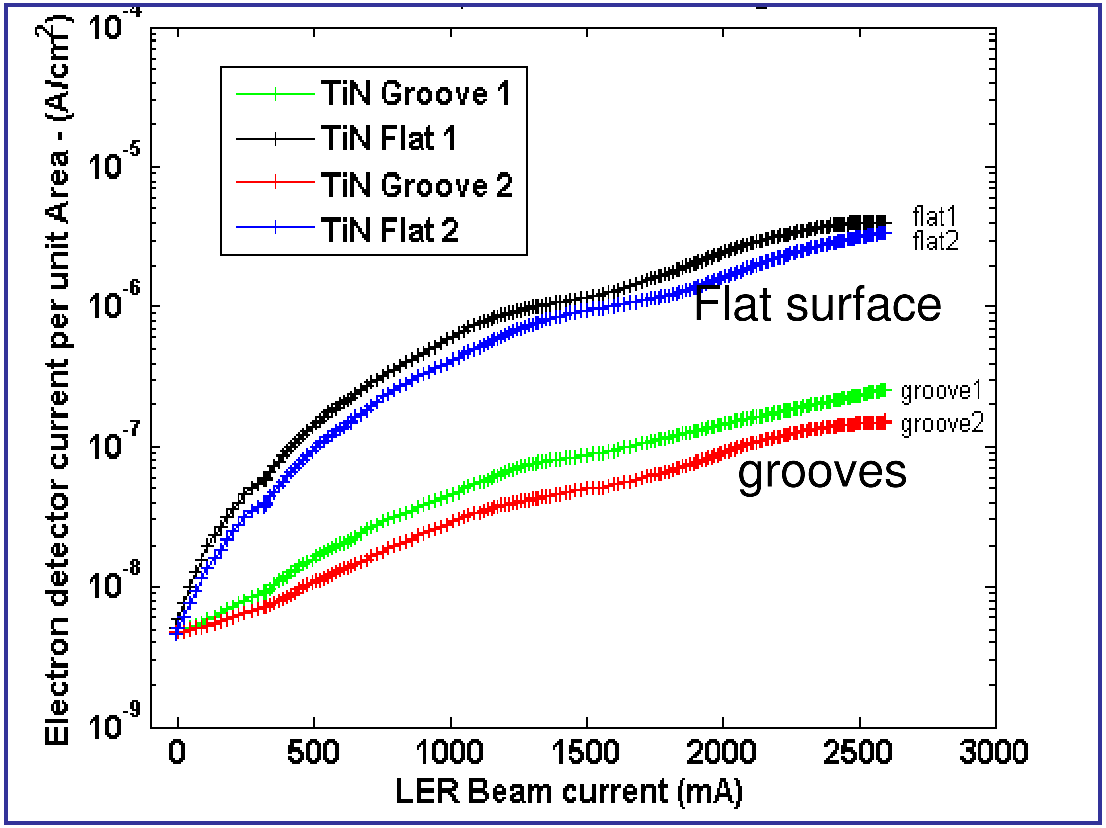
Surface top view

CSIC
CONSEJO SUPERIOR DE INVESTIGACIONES CIENTÍFICAS
INSTITUTO DE CIENCIA DE MATERIALES DE MADRID (ICMM)

E-cloud suppression with grooves (M.Pivi, SLAC)

E-cloud detection in straight section of PEPII





Al extrusion
+TiN coating

grooves

…and in a dipole (M.Palmer, M.Pivi)

- Current scan in L3 Chicane, 1x45 e+, 14ns, 5GeV (chicane of SLAC to Cornell
  - Note: Al signal is divided by 20 to show on the same scale
  - Grooved chamber has **5mm deep** 20° triangular grooves with TiN coating

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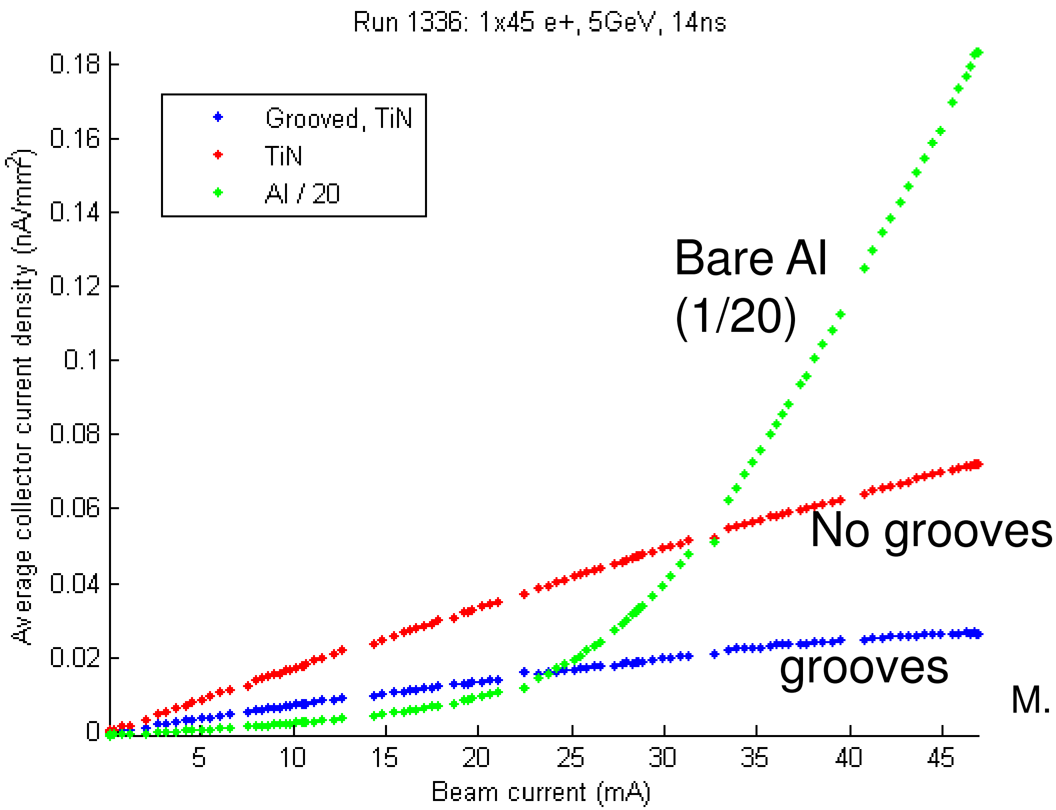

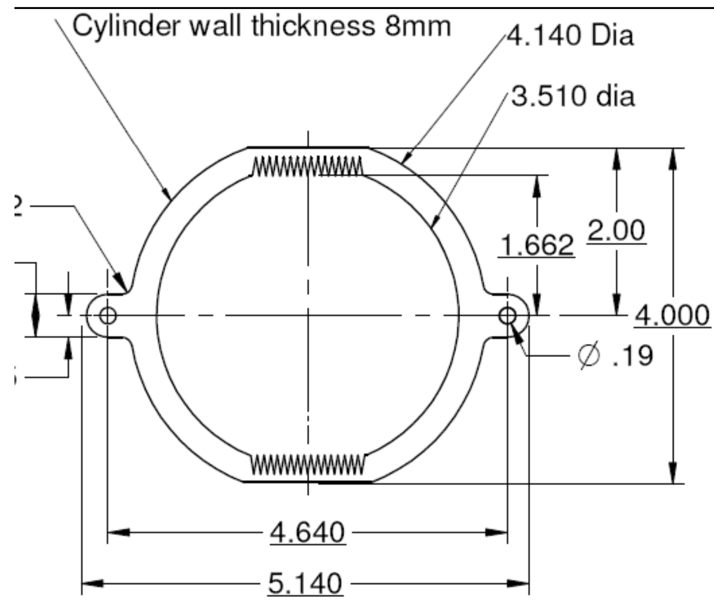

M. Palmer Cornell