Recent experience with enamel coating technology for accelerator applications at CERN

F. Caspers, E. Mahner, B. Henrist, J.M. Jimenez

Outline

- What is the concept (PS)
- Where did we go so far
- Which problems and good news have been seen
- What are possible options for the future

What is the concept (1)

The SPS e-cloud measurements 2008

Status and near future planning

F.Caspers, J.Jimenez, E. Mahner, T. Kroyer

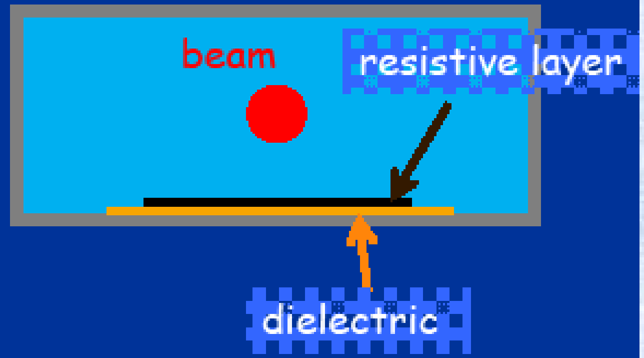
- The SPS e cloud experiment near point 5 consists essentially of 2 parts
  - "conventional" (but improved) electron collectors with stripline electrode on the opposite wall (like used in the PS In 2007)
  - Several microwave transmission setups (like the first experimental version from the SPS in 2003)
- The aim is to compare the results of both experiments for cross-calibration and also to check the applicability of enamel technology.
- The present status is, that machining of hardware and ordering of electronic components continues.

SPSU 22.Jan 2008 e-cloud in the SPS; Caspers, Jimenez, Mahner, Kroyer 1

What is the concept (2)

Low-impedance electrodes

- Electrodes implemented as a resistive coating can be used to minimize the impedance. They are basically “invisible” electrodes in the sense that they are much thinner than the penetration depth and thus do not interact strongly with the beam fields. Another condition for a low coupling to the beam field is that the coating's surface resistance is much larger than the free space impedance of 377 Ω.
- Such an electrode behaves almost like a dielectric layer.

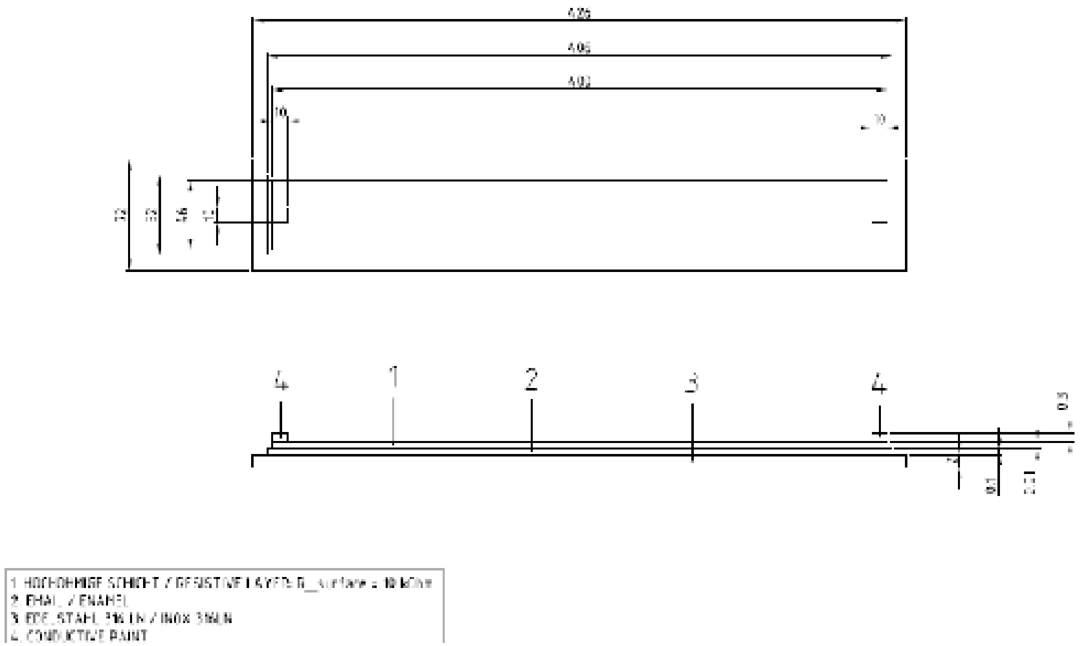


- In practice, a solution could consist of a dielectric layer made of enamel or alumina for the dielectric isolator. A resistive coating as the actual electrode is deposited on top of the dielectric.
- Such a structure in particular has good mechanic stability and good thermal contact to the beam pipe; for a thin dielectric the aperture reduction is small.

T. Kroyer, E. Mahner, F. Caspers, CERN   LHC MAC, 7.12.2007   10

What is the concept (3)

Enamel electrode for the SPS setup



That item should arrive at CERN this week from Düker-works and will be installed immediately

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What is the concept (4)

New planar enamel clearing electrode (2008)

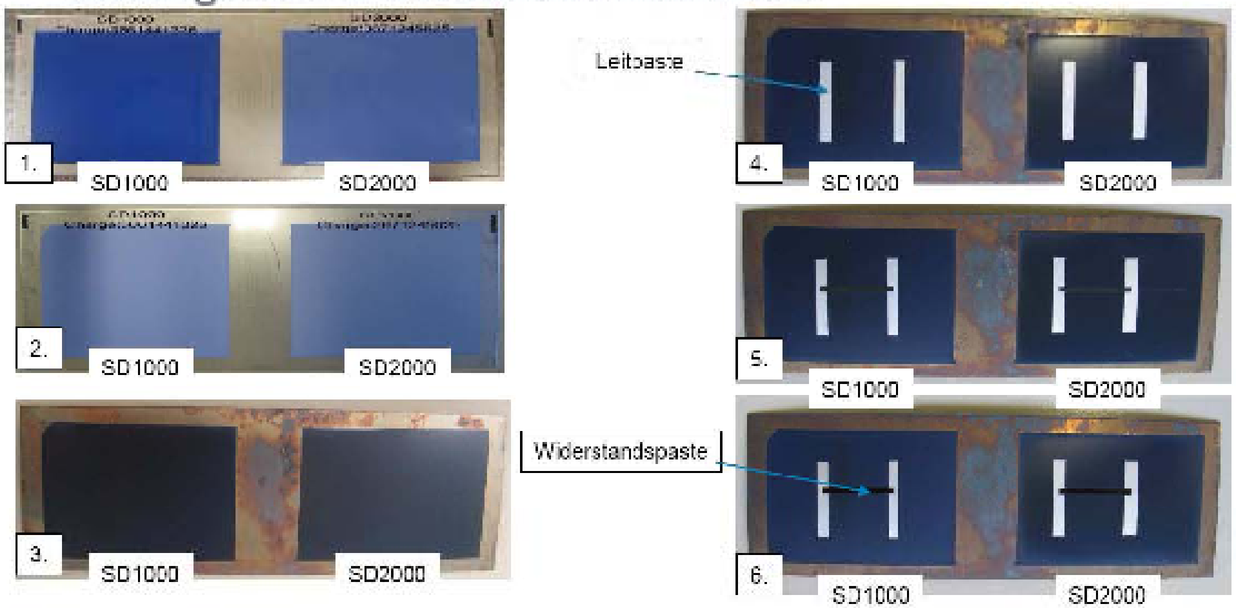
What is the concept (5)

Recent results with ceramic coatings from Heraeus (1)

Tests with ceramic PAINT on steel

S. Malkmus Heraeus

Untergrund SD1000 und SD2000



Ergebnis: Optisch in Ordnung

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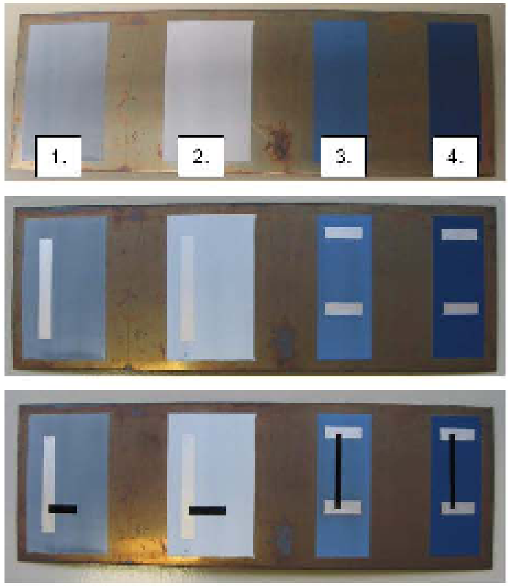
What is the concept (6)

Recent results with ceramic coatings from Heraeus (3)

Tests with ceramic PAINT on steel

S. Malkmus Heraeus

Untergrund 1. – 4.



Ergebnis: Optisch in Ordnung

Dielektrikapasten: Name/Charge

1. GPA94-085/3662942580
2. GPA99-048/EI1533 (= 4. ohne Co)
3. IP9227/3672847072
4. IP9117E/PI3295

Leitpaste: Name/Charge
C1076SD/3644935883

Widerstandspaste: Name/Charge
R8931D/3653038561

Thickness of these coatings:

About 30 micron for the isolating layer

About 20 micron for the resistive layer

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Other Tests done by Heraeus (1)

(Firing of ceramic TAPES on steel)

Heraeus

Übersicht

- **Die nicht magnetischen Stähle wurden von CERN „European Organization for Nuclear Research“ bereitgestellt. Typ 316 LN**
- **Da Co kein Bestandteil des Tapes sein durfte, war die Auswahl auf CT701 und Variationen begrenzt.**
- **Versuche mit Heraeus CT701 und AHT07-035**
- **Trotz Co Vergleich mit AHT99-042 (bekanntlich sehr gute gute Haftung zu Stahl)**
- **Weitere Versuche analog mit Pasten (mit und ohne Co)**
- **Als R-Paste kommt eine 1k oder 10k Ohm Paste in Frage**

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Other Tests done by Heraeus (2)

Heraeus

AHT99-042 und CT701

Uniaxial laminiert:
70℃, 10min mit 220KN
auf einer Fläche von
75 cm² (15 cm x 5 cm)

Bild oben: 1 x laminiert und gebrannt → keine Haftung bei AHT99-042

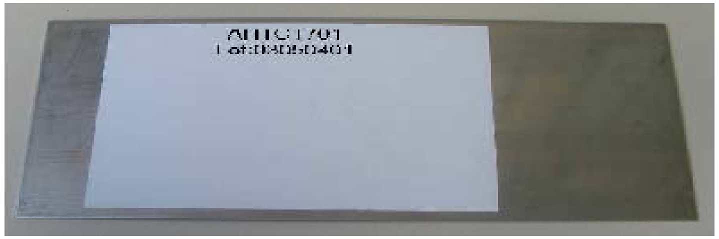

Bild unten: 1 x laminiert und gebrannt → Haftung bei CT701

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Other Tests done by Heraeus (3)

Heraeus

AHT07-035

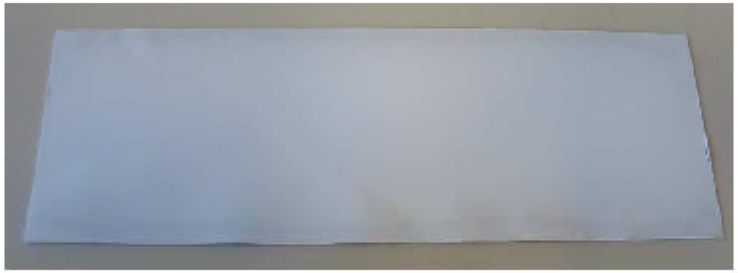

Bild oben: 2 x laminiert → keine Haftung

Uniaxial laminiert:
70℃, 10min mit 220KN
auf einer Fläche von
75 cm² (15 cm x 5 cm)

Bild unten: 1 x laminiert und gebrannt → keine Haftung

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Other Tests done by Heraeus (4)

Heraeus

CT701 Proben gebrannt + gebogen

gebogen nach Einbrand → Rest haftet recht gut.

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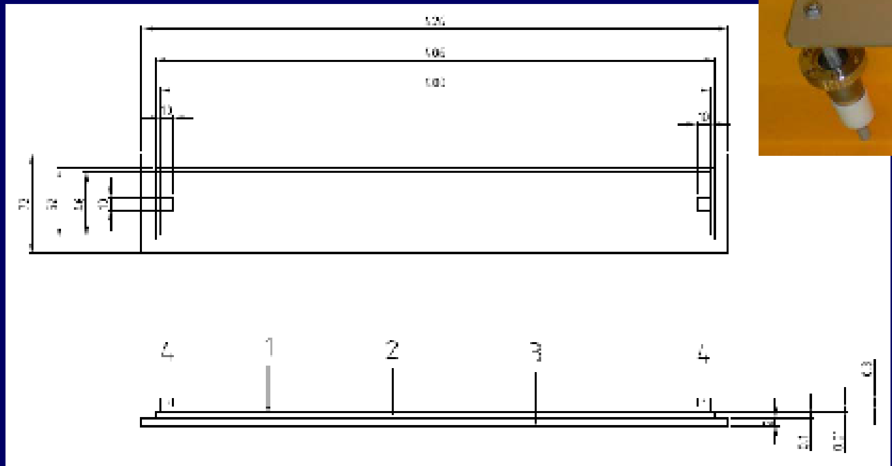
Where did we go so far (1)

Electron cloud detector in PS – SS84 installed in 2008

Very similar to the PS 2007 experiment in SS98, but stainless steel clearing electrode replaced by a new enamel electrode.

Stainless steel clearing electrode (2007)



Enamel electrode with dimension 426 x 72 x 2.1 mm

(4) Conductive paint
(1) Resistive Layer with R ≈ 10 kΩ (0.01 mm)
(2) Enamel (0.1 mm)
(3) Stainless steel 316 LN (2mm)

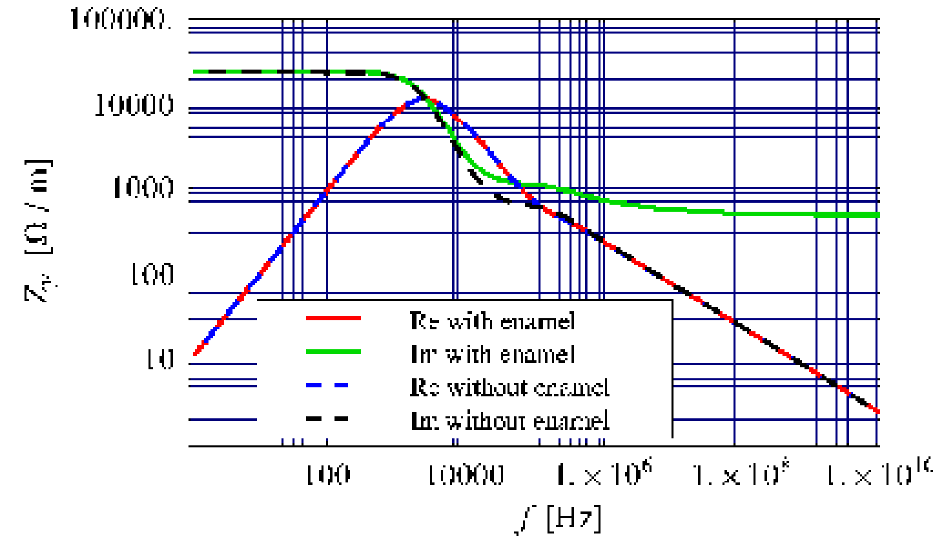
New enamel clearing electrode (2008)

E. Mahner VAC Sci. Committee 2008-06-02 9

Where did we go so far (2)

Transverse impedance

- The transverse impedance was estimated analytically for structures with rotational symmetry using the Burov-Lebedev formula and simulated using CST Microwaves Studio and HFSS [1]
- To first order the increase in Z_{TR} is purely imaginary and frequency-independent;
- Preliminary results scaled to one 0.1 mm thick centered electrode with ε = 5 all along the SPS (pipe radius 25 mm, electrode width 15 mm): $Im(Z_{TR,y})$ = 4 MΩ/m (entire machine today: Z_{TR} ~ 20 MΩ/m)



[1] T. Kroyer, F. Caspers, E. Metral, F. Zimmermann, Distributed electron cloud clearing electrodes, Proceedings of the ECL2 Workshop, CERN, Geneva, 2007

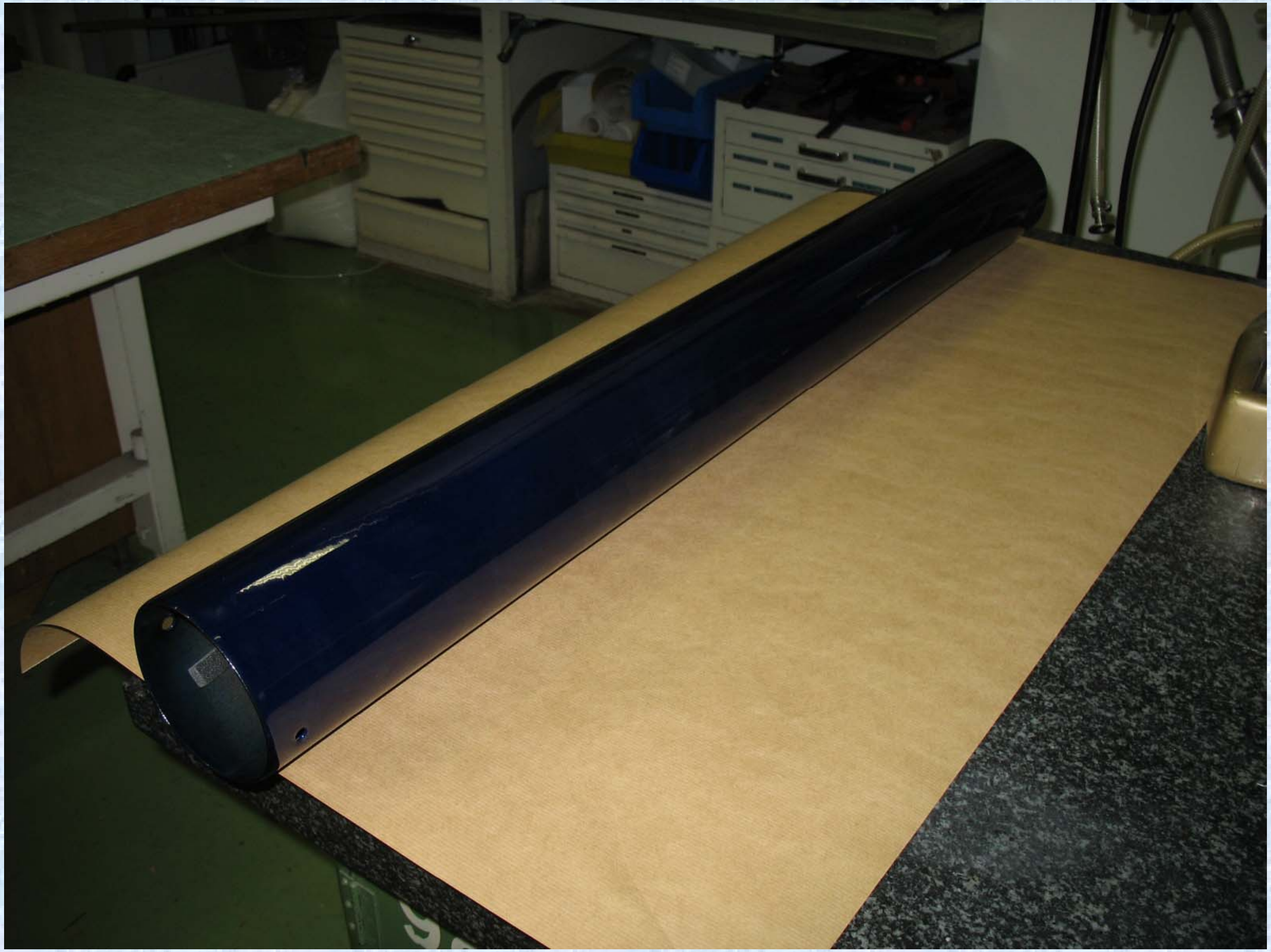
plot courtesy: E. Metral

Where did we go so far (3)

Electron cloud studies in the SPS and PS measurement program (2/2)

- SPS study bench
  - Electron cloud characteristics
    - Reference pickups (same as used last year in PS ss98) to follow the build-up.
    - Electron repelling detector to measure the surviving (low energy) electrons after LHC beam passage
    - New clearing electrode setup to "validate" the enamel technology.
  - SEY yield and XPS measurements
    - Experiment on the "C" magnets, a chamber with a "sas" and a manipulator shall allow extracting under vacuum a sample exposed to the electron bombardment. The bombarded sample will then be measured (SEY & XPS) in the Lab [TS-MME].
- PS study bench
  - Electron cloud characteristics
    - "Reference" setup in ss98 (pickups, clearing electrode, small dipole field)
    - New clearing electrode setup in ss84 to "validate" the enamel technology.

Another example of enamel coating application for 25 KV insulation
(cold bore of the future inner triplet at 4.2 K in LHC , photos by S. Calatroni)



Radiation dose
60 Mega Gray

Which problems and good news have we seen?

During the last injector MD in week 41 first comparative results between the stainless steel (SS98) and enamel (SS84) electrodes was made in the PS using the nominal 25 ns LHC beam. The enamel electrode acts very similar in terms of electron cloud suppression as the metallic electrode used last year. Thus the functionality of enamel technology as clearing electrode material has clearly been demonstrated. C.f. talk by E.Mahner on this subject (this workshop)

As for the resistively (high impedance) coated enamel electrodes we noticed that there might be a diffusion of the resistive paint which is to be fired in air at 850 deg C in the enamel base layer leading to local bridge formation to ground
It would perhaps be better to use a resistive layer which has a lower melting point

So far we have only managed to produce those enamel resistive paint coatings on FLAT surfaces ...no good ideas in sight how to do it easily AND reliably on an elliptic or round beampipe over a considerable length.

For the Heraeus ceramic coatings one can certainly do it on flat surfaces but no easy solution is in sight for round or elliptic tubes.

What are possible options for the future?

Improvements on presently used technology (enamel and ceramic coatings)
But exactly which way to go?

Should be try new coating techniques for ceramic layers?

Any other suggestions?

Unless we dont find a good, robust and not too expensive solution for INNER coating of long tubes we have to stop here. Remember that all those items are usually fired in air at around 800 C or more and get out from the oven with considerable oxide layers...

Where did we stand at ECL 2 about 18 months ago?