



Electron Clouds in the SPS: progress in the analysis of cures/mitigations measures and potential schedule of implementation

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This talk is a summary of my views meant for a recommendation.

For detailed results and pictures, please report to presentation given by M. Taborelli (TE/VSC on behalf of SPS-U SG) during the LIU Day

<http://indico.cern.ch/conferenceDisplay.py?confId=112934>



- **Introduction**
- **Review of the studies made so far**
- **Proposed milestones**
- **Closing Remarks**

Acknowledgments:

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(my apologizes for the missing names/groups)



- **Operating the SPS with:**
 - High bunch intensity, up to $2.5 \cdot 10^{11}$ p/bunchand
 - Small emittances (LHC requirements)

cannot be guaranteed since **electron cloud limitations** have been identified:

- Pressure rise: beam gas scattering, dose rates to tunnel and components
 - Beam instabilities: transverse emittance blow-up and single bunch vertical instability
-
- **This statement is **confirmed** by many studies and MDs carried out in the frame of the SPS-U Working Group chaired by E. Shapochnikova**
 - Identification and understanding of the potential limitations
 - Significant progresses made on the effects on beams
 - Beam scrubbing and other mitigation solutions mainly amorphous carbon a-C studied in the SPS



Review of the studies made so far

Beam Scrubbing



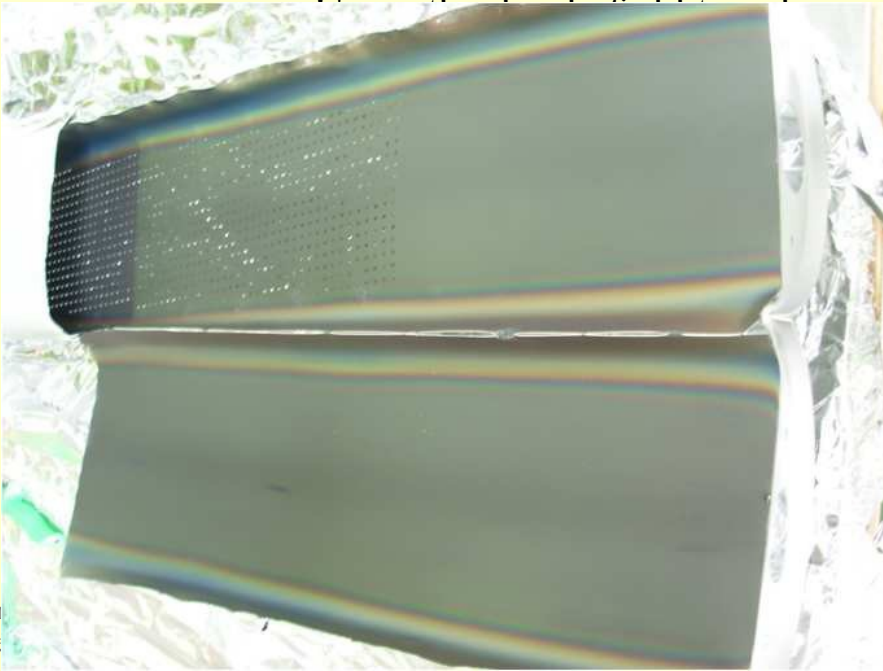
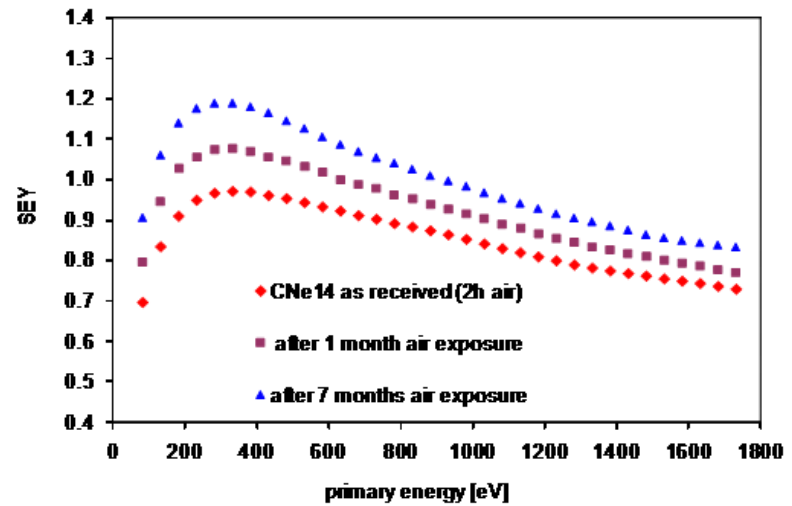
- **Beam scrubbing is successfully used since 1999 to reduce the electron cloud activity, BUT:**
 - **Suppression** was never achieved except in field free regions
 - Residual electron cloud activity in the bending sections after 1 week of scrubbing
 - Corresponds to a **mitigation** solution and NOT to a suppressing method
 - Has an **intrinsic limitation**
 - Reaching smaller SEY (δ) need larger electron bombardment doses (log behaviour)
 - The closer to the threshold for a given bunch population and the lower the electron bombardment dose
- **Electron cloud is a threshold mechanism with a build-up varying with train length**
 - Use higher bunch population and smaller bunch spacing during scrubbing
 - Run at lower bunch population and larger bunch spacing
 - ☞ Allows to profit from threshold effect, NO build-up

Review of the studies made so far

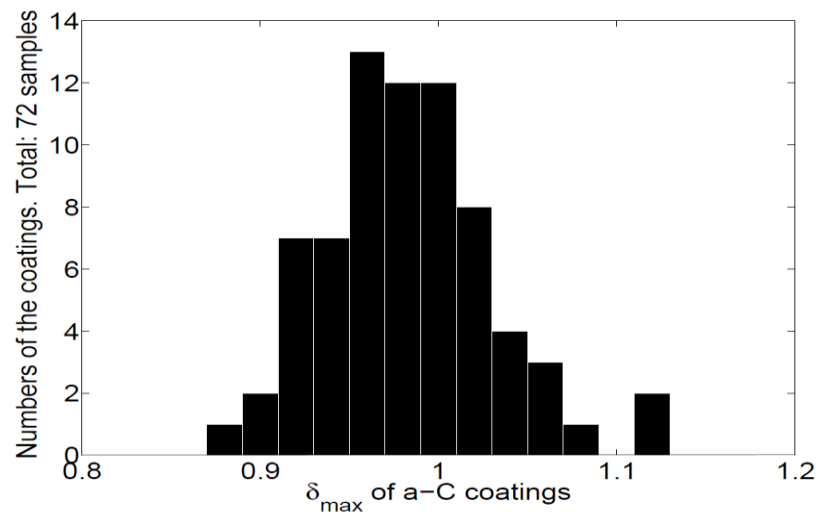
Coatings (1/3)

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- **Feasibility and Status-of-the-art**
 - **Magnetron sputtering** is a mastered techn
 - **Amorphous carbon (a-C)** selected since:
 - Provides low SEY (<1.2) and is only sligh
 - Does not require any activation (bake-out
 - Two options are possible:
 - Coating made **without removing** the bean



...er looks more promising, successfully tested





Review of the studies made so far

Coatings (2/3)



- **Hard limits and Open questions**

- Diagnostics available in the accelerator
 - **Indirect measurements** of coating efficiency, not always very conclusive
- Coating optimization
 - **Cleaning** the beampipe prior to coating is a concern: easier to do on a new beampipe
 - Studies made in Bld867 on 15 magnets showed no activation of the liquids used
 - **Lower deposition** rate to keep magnet's temperature to stay below 150°C during the coating
 - **Outgassing rate** is 10 times higher (static vacuum)
 - Considering to coat only part of the top/bottom surface
 - **Lifetime** and **peel** off is of concern, positive feedback so far
 - 1-2 year without ageing observed with samples installed on an ecloud monitor
 - No evidence of peel off, good adherence
 - » No dust coming out from the samples, event though exposed to electron bombardment and radiation dose
 - Limited effect of venting, more studies needed
 - **Acceptable electron cloud load** from remaining non-coated length?
 - Short straight sections, radiation and alignment issues, etc.



Review of the studies made so far

Coatings (3/3)



- **Required infrastructures and tooling**

- Option to do these activities in a **building at the surface** has major disadvantages
 - No building available, building a new one is not compatible in term of schedule and costs
 - Too many transports will increase the duration
- Go for **ECX5 cavern** solution (done for magnet consolidation campaign)

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- **Schedule implications**

- **Coating of the existing magnet** beampipes is the preferred solution
 - Transport dominates (up to 4 stands in parallel)
- **Inserting a new coated chamber** will be difficult to do in the ECX5 cavern
 - Faster for coating BUT much more demanding for Magnet crew
 - Duration of magnet opening and closure dominate by far all activities if we go for new beampipes

- **Phasing feasibility**

- Yes BUT only if **shutdown duration are at least 4 months**: 3 shutdowns required
 - Preparation and dismantling of ECX5 is taking time



Review of the studies made so far

Clearing electrodes (1/2)



- **Feasibility and Status-of-the-art**

- **Vertical configuration** to take into account the trapping of the electrons spiraling along the dipole field lines
 - Not pushed forward since resulting in a aperture restriction (~1 mm in total)
- **Validated at low magnetic field** in the PS
- Studies are **much less advanced** than coatings

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- **Hard limits and open questions**

- Required **clearing voltage** to be assessed
 - Can we find a value that works for all energies and beam characteristics?
 - Cost and maintenance of the cabling and required power supplies
 - Long term reliability: active system with feedthroughs
- Results in a **vertical aperture restriction** and impedance issue
- Difficult to equip the **quadrupoles** and **short straight sections**
- Engineering issues
 - Equipping new chambers will result in a significant increase in cost since mechanical tolerances for manufacturing (twist and straightness) shall be significantly decreased as compared to existing beampipes



Review of the studies made so far

Clearing electrodes (2/2)



- **Required infrastructures and tooling**
 - **Similar** to the one to be prepared for **coatings**
 - In the tunnel, in ECX5 cavern
 - In the surface, in an existing building or by building a new one
 - **Retrofitting** in existing dipole chambers will require development of **complex tooling**
- **Schedule implications and Phasing feasibility**
 - As for the coatings, phasing can be foreseen
 - Must equip at least 2/3 of the SPS ring to be able to see an effect
 - **Transport time dominates** if retrofitting the clearing electrodes in existing beampipes
 - Duration of **magnet opening and closure** dominate by far all activities if we go for new beampipes



Review of the studies made so far

High bandwidth feedback systems (1/3)



- **Feasibility of the high bandwidth feedback system**

Study being carried out in the framework of LARP, this system requires:

- **New pick-up** for high bandwidth feedback system
 - Long strip lines (at least 1.5 m)
 - Complex design (accuracy and 50 Ohm impedance)
 - Technically challenging but feasible
 - Can be done at CERN, collaboration RF/MME?
- **New kicker** for high bandwidth feedback system
 - Complex design
 - Technically challenging but feasible
 - EM Simulations can be done by L Berkeley Lab in the framework of LARP
- **High speed digitization and digital treatment**
 - Prototype system being developed in the framework of LARP, will be able to treat a small number of bunches only

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Review of the studies made so far

High bandwidth feedback systems (2/3)



- **Potential “showstoppers”**
 - Emittance growth could be dominated by **incoherent effects** which cannot be damped
 - Excessive **power required** to correct effects on all bunches due to the fast growth rates
- **Challenging but not thought to be “showstoppers”**
 - Adjustment of the **loop delay** will be very delicate for the high frequency high bandwidth system (GHz)
 - **Mix-up** with longitudinal motion possible if bunches not stable longitudinally
 - Suppression of **common mode signal** crucial to avoid amplifier saturation and to allow good usage of dynamic range available
 - Could be **required to split** the system into several bands in order to be able to cover the entire frequency range



Review of the studies made so far

High bandwidth feedback systems (3/3)



- **Required infrastructures**

- Electronics and amplifiers shall be **partially installed in the tunnel** close to the wide-band pick-up and kickers
 - Radiation and shielding issues, could require civil engineering: platform, concrete shielding
- New pick-up and kicker need modifications in the **tunnel**
 - Layout modification, electronics, hardware and significant cabling
 - Preferred location BA3 (dispersion suppressor), alternatively BA5

- **Schedule implications and Phasing feasibility**

- **Demonstrator** for wide-band feedback
 - Installation could take place during the **2011-12** winter stop (cabling)
 - Validation of FB with demonstrator in **2013** → decision for go-ahead
- **Final system** with new pick-up and kicker
 - **Pick-ups** and **kicker** could be ready for late **2013**
 - Final version of **electronics** could be available 2 years after complete validation with demonstrator: **2014-15**
 - **Layout** modification and cabling could be advanced to **2012**



Proposed milestones



- **Feasibility** studies on clearing electrodes
- **Industrialisation** of a-C coatings
- **Enhancement** of electron cloud for scrubbing purposes

Deadline: end Sept'11

- **Development of additional electron cloud diagnostics**
- **SPS MD measurements to validate efficiency of proposed solutions**

Deadline: end Sept'11

- **Preparation of a prototype section: 1 or 2 half-cells for 2011-12 Technical Stop**
 - With all diagnostics

Deadline: end Dec'11

- **Proceed to a complete evaluation**

Deadline: Sept'12

- **Define the strategy for 2013**

Deadline: Oct'12 (Chamonix is too late)

- **Installation of the pilot sector**

During shutdown 2013

- **Validation using a pilot sector (half an arc ?) as from 2014 until 2017-18 shutdown:**

Deadline for final decision: end 2016

- **Full installation:**

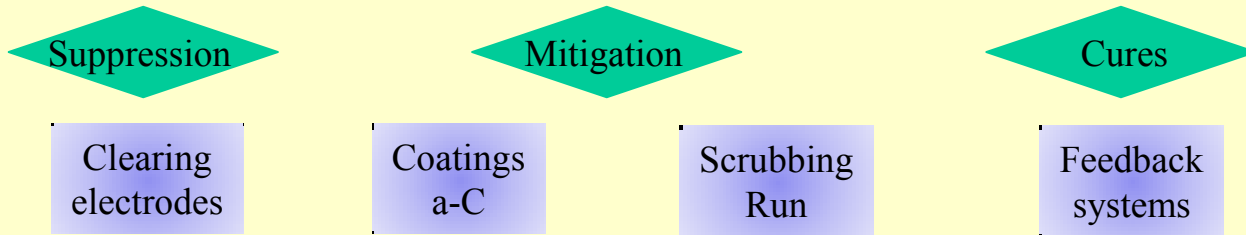
Shutdown 2017-18



Closing Remarks



Existing accelerator
limited by electron
cloud



Status in '10

R&D completed	N	Y	Y	Y/N
Prototyping	N	Y	-	N
Validation	N	Y/N	Y/N	N
Industrialisation	N	Started	-	Y/N

Status in '11

R&D completed	Y	Y	Y	Y
Prototyping	?	Y	-	Y/N
Validation	Y/N	Y	Y	N
Industrialisation	N	Y	-	Y/N

- **Suppression: Clearing electrodes**

- Aperture, impedance, technical solution, full-scale feasibility, lifetime, quads, LSS, cabling, powering, etc.

- **Mitigations**

- a-C coatings
 - Lifetime, stability with venting, outgassing
- Scrubbing runs
 - Feasibility and margin, MD time.

- **Cures**

- High bandwidth feedback systems
 - High speed digitization and digital treatment

- **Simulations**

- **E-cloud budget**, stability expected, emittance growth, impedance from electrodes, effectiveness of bandwidth feedback, etc.
- *If we rely on beam scrubbing in the LHC why not in the SPS?*

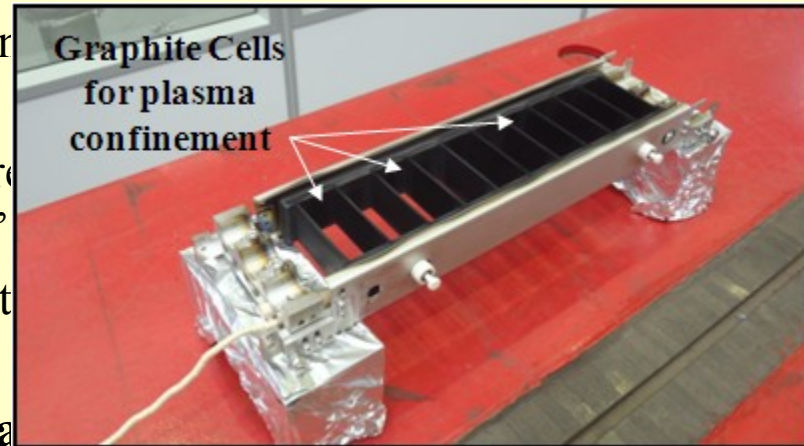


Closing Remarks

Priorities *versus* Resources

- **Satisfactory situation with mitigation solutions**

- Scrubbing run is scheduled, MMDs have been
 - We'll also learn from LHC scrubbing run
- Coating are progressing well, new approach re promising results from the “industrialization”
- Strengthen efforts on diagnostics to improve t solution with beams in the SPS

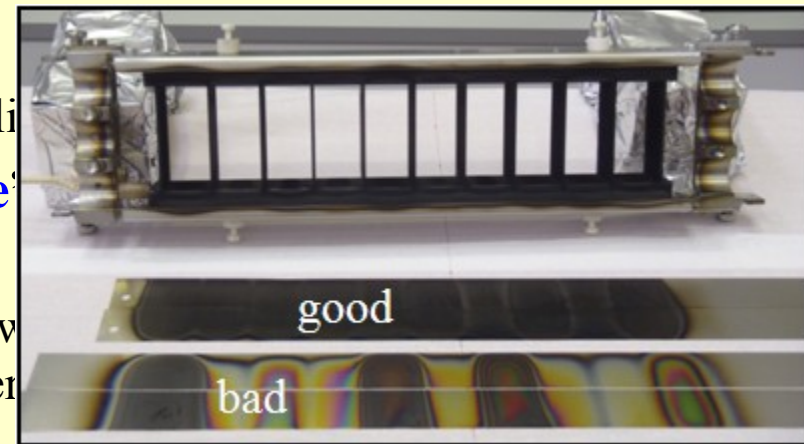


- **Feedback systems can be on track with rea**

- Collaboration framework (LARP) exist
- Engineering and manufacturing to be internali

- **Clearing electrodes running “out-of-phase” studies**

- Resources to be allocated to achieve a status v are still reasonable in theory, in practice, when
- Going for industrialization is another story...



Hollow cathode squared cell prototype