Vacuum issues

CAS INTENSITY LIMITATIONS

Paolo Chiggiato, CERN

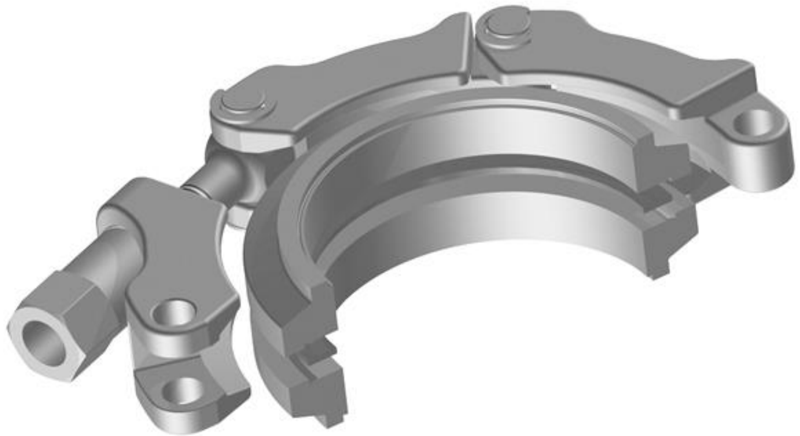
Outline

- **Safety issues**
- **Beam induced desorption (gas load) and multipacting**
- **Mitigations other than beam conditioning**
- **Heating**
- **Conclusions**

Safety issues

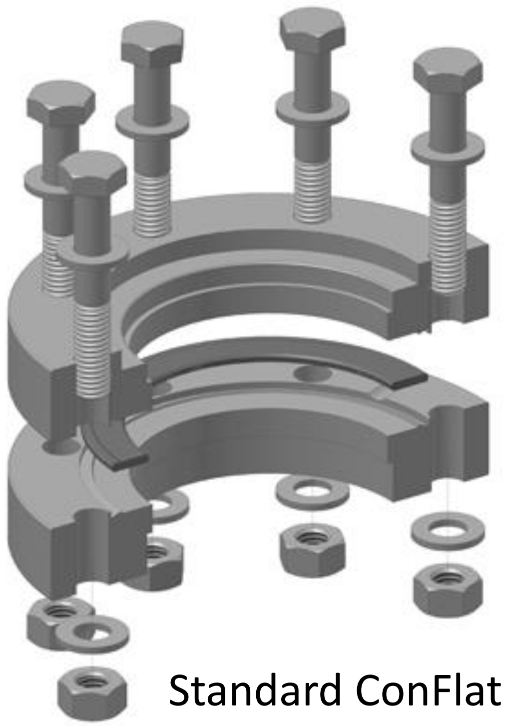
- Higher intensity means **higher losses** and **higher doses** of intercepted particles in collimators and dumps
- From the very beginning, layout and equipment exposed to the beam have to be designed so that the **collective radioactivity dose is minimized** in the spirit of the ALARA procedure.
- For example, the **localization** of components that require regular maintenance have to be selected with care.
- Components have to be **easily and reliably operated** by the personnel.
- An example:

Courtesy of Vacom



Quick connect ConFlat flange

Courtesy of Vacom



Standard ConFlat flange

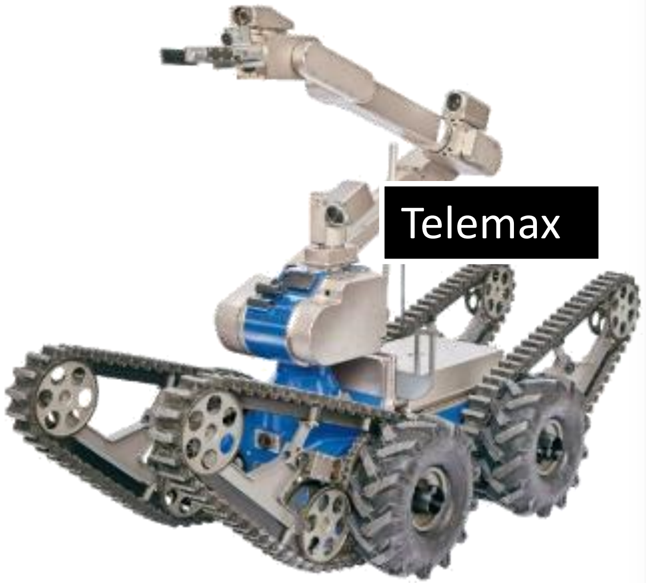
Safety issues: robot intervention

- The design of accelerators should facilitate robotic interventions.
- Robotic intervention for vacuum activities is already a reality.
- During the Long Shutdown 1, Telemax was used in the SPS and its experimental lines

Use of robot for:

- Inspection of equipment
- Leak detection
- Removal of clamps
- Cleaning
- Install flanges (12 mSv/h)

Courtesy of J. A. Somoza Ferreira



Leak detection with remote operated robot

Safety issues: robot intervention

Limiting factors:

- Costs
- Need of trained personnel
- Time consuming
- Remote operation

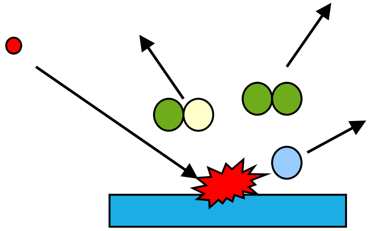
<u>Example: remove 1 clamp</u>

Human with torque wrench:	2-3 minutes
Human with cordless impact wrench:	20-30 seconds
Robot:	15-30 minutes

Plenty of development for the next generation of designers of high-intensity accelerators

Gas load: beam induced desorption

The impingement of electron/photon/ions on surfaces can result in ion and neutral gas desorption.



In **1918**, Dempster observed ion desorption from electron bombarded salts (Phys. Rev. 11, 323)

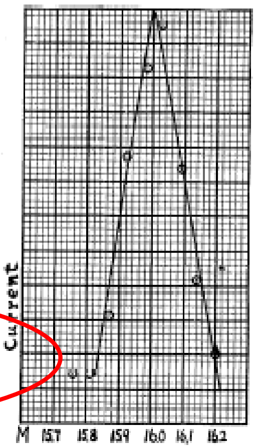
Vol. XI.] No. 4. POSITIVE RAY ANALYSIS. 323

POSITIVE IONS FROM ELECTRON BOMBARDMENT.

It was thought that the bombardment of salts by electrons might break up the chemical compounds and give rise to many positive ions. At first a Wehnelt cathode was used; the ions formed passed beside the cathode (Fig. 1) and were then accelerated by a large potential difference. Aluminium phosphate on a piece of platinum foil was first bombarded. The intensity of the rays increased very rapidly with a slight increase in the amount or energy of the bombarding electrons, indicating that the salt needs to be heated to a certain degree before the ions are separated. Although the aluminium phosphate was chemically pure, the rays obtained under the bombardment of 128 volt electrons were very complex; the following ions were observed besides a couple of unresolved groups; H_1, H_2, Li (weak), O_1 (strong), Na (strong), O_3 (?) (weak), $M = 62$ (weak, possibly Na_2O), $M = 67$ (strong, possibly $H_3PO_3 = 66$), $M = 76$ (strong), $M = 86$ (weak, possibly $Rb = 85.5$), $M = 112$ (strong, possibly $P_2O_3 = 110$).

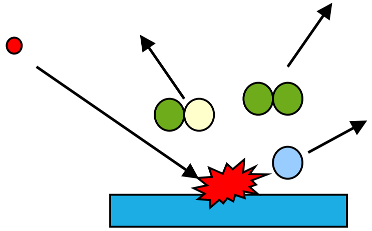
The experiments indicated the convenience of the method of obtaining positive rays and opened up an interesting field for investigation.

The experiments were however first directed



Gas load: beam induced desorption

Millikan reported the first evidence of **photon induced desorption** in 1909 during the measurement of the photoelectric current of metals exposed to ultraviolet radiation.



The first interpretation is given by Winch in 1930 (Phys. Rev. **36**, 601).

He was the first to see the implication of photoelectrons on photon induced desorption.

Outgassing

specimen to ultraviolet fatigue curves, taken by leaving the specimen in a vacuum of 10^{-7} mm of Hg unexposed, showed during the first stages a rapid decrease in photocurrent with time of standing, but, after 360 hours of exposure for the film and 160 hours for the solid gold, the photo-current from the former held constant for 3 hours, and from the latter 1½ hours. This seemed to indicate that a fairly stable equilibrium had been reached, and the subsequent fatigue was consistent with the idea that it was due to return of gas to the surface.

The experiment was repeated, using a silver filament approximately 0.025 mm thick, and an increase in emission comparable to that for the gold film was obtained.

The probable explanation is that photoelectrons, both when ejected and returned to the surface by a reverse field, remove adsorbed gas from the surface.

Millikan[1] noted an increase in photoelectric emission on exposure of certain metals to ultraviolet, but did not note the corresponding change in long wave-length limit or that the photoelectrons themselves apparently play an important part in the outgassing.

Work is being carried forward testing this explanation and obtaining more data on photoelectric properties of thin films.

Ralph P. Winch
Laboratory of Physics,
University of Wisconsin,
Madison, Wisconsin,
July 15, 1930.

[1] Millikan, Phys. Rev. 29, 85 (1909).

The probable explanation is that photo-electrons, both when ejected and returned to the surface by a reverse field, remove adsorbed gas from the surface.

Gas load: beam induced desorption

The **desorption yield** η, i.e. the number of molecules desorbed per impinging particle, is the quantity needed to design vacuum system of particle accelerators:

$$\eta = \frac{\textbf{number of molecules desorbed}}{\textbf{number of particules impinging on the surface}}$$

η depends on many parameters, in particular:

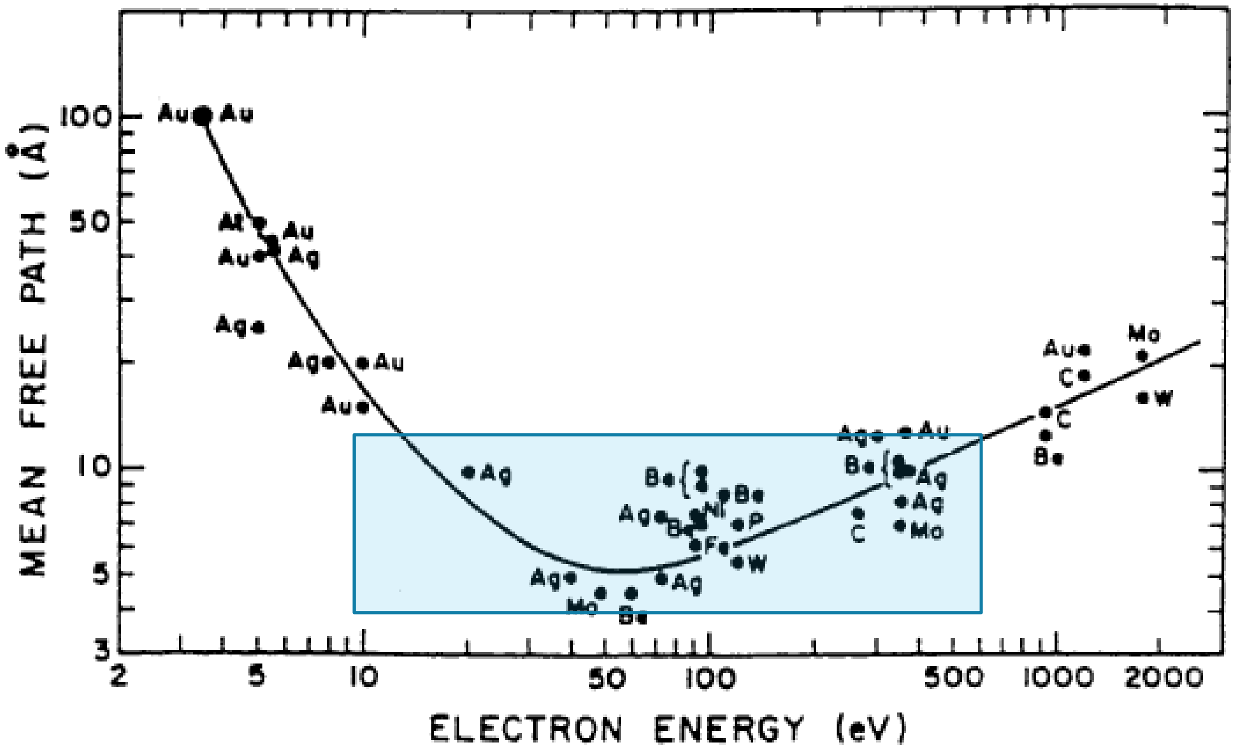
- on the nature and energy of the **impinging particle**;
- the **material** of the vacuum chamber;
- the nature of the **desorbed gas**;
- quantity of particles that have already impinged on the surface, namely **the dose D** $[\text{particles}/\text{cm}^2]$.

The **cleanliness of the surfaces** has also a crucial influence.

Gas load: Electron Stimulated Desorption (ESD)

In general, ESD is correlated with beam induced **multipacting** (ecloud in beampipes and multipacting in RF systems).

The **penetration depth** of electrons kicked by beams is **lower than 1 nm**. ESD strongly depends on the chemical composition of the **oxide layer** (typical thickness is 1-10 nm).



Universal curve for inelastic mean free path as a function of electron kinetic energy.
M. Seah and W. Dench, Surf, Interface Anal. 1(1979)2

Gas load: ESD, selected case 1

OFHC copper, cleaned following CERN recipe, stored in plastic bag for weeks, 24 h pumping, ***not baked in situ***.

$$\eta(E) = \eta(E_0)\left(\frac{E - E_0}{E_0 - E_c}\right)^{\gamma}$$

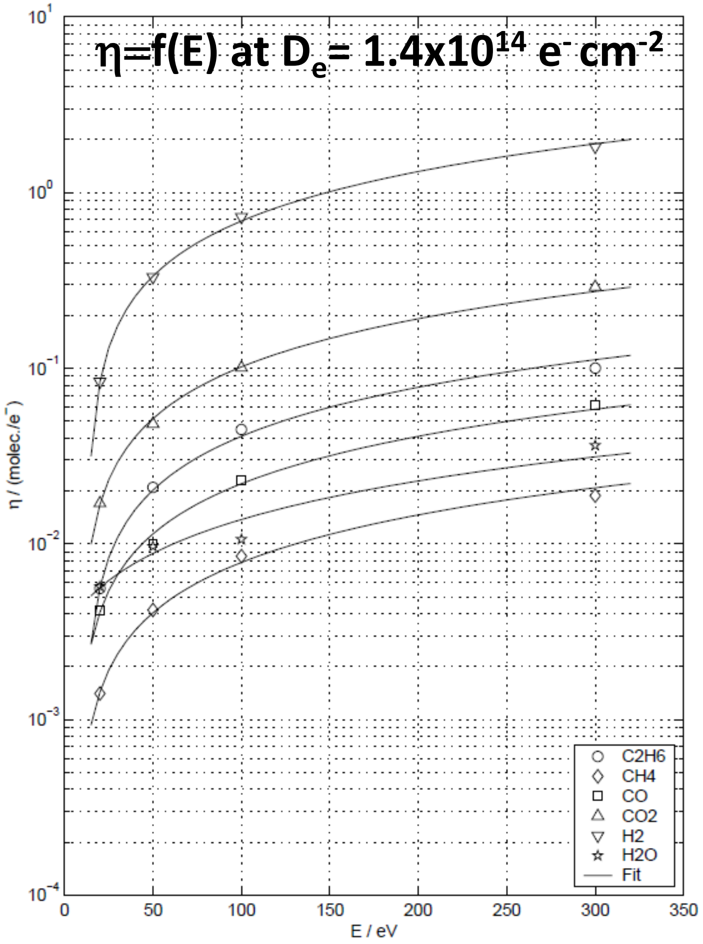
$E_0 = 300 eV$

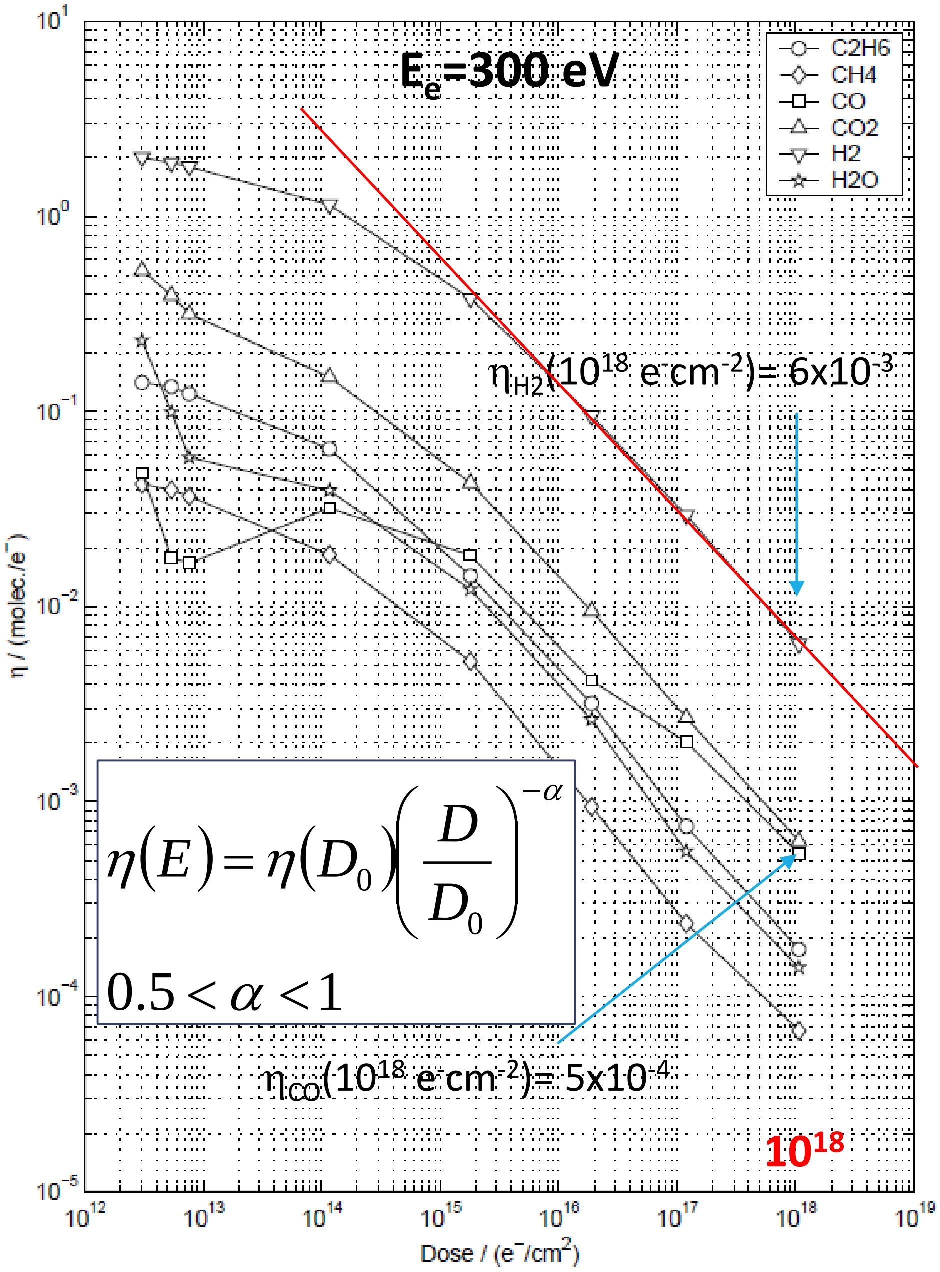
$\gamma = 0.85$

E_c cut off electron energy

$\rightarrow \eta(E_c) = 0$

$E_c \approx 10 eV$

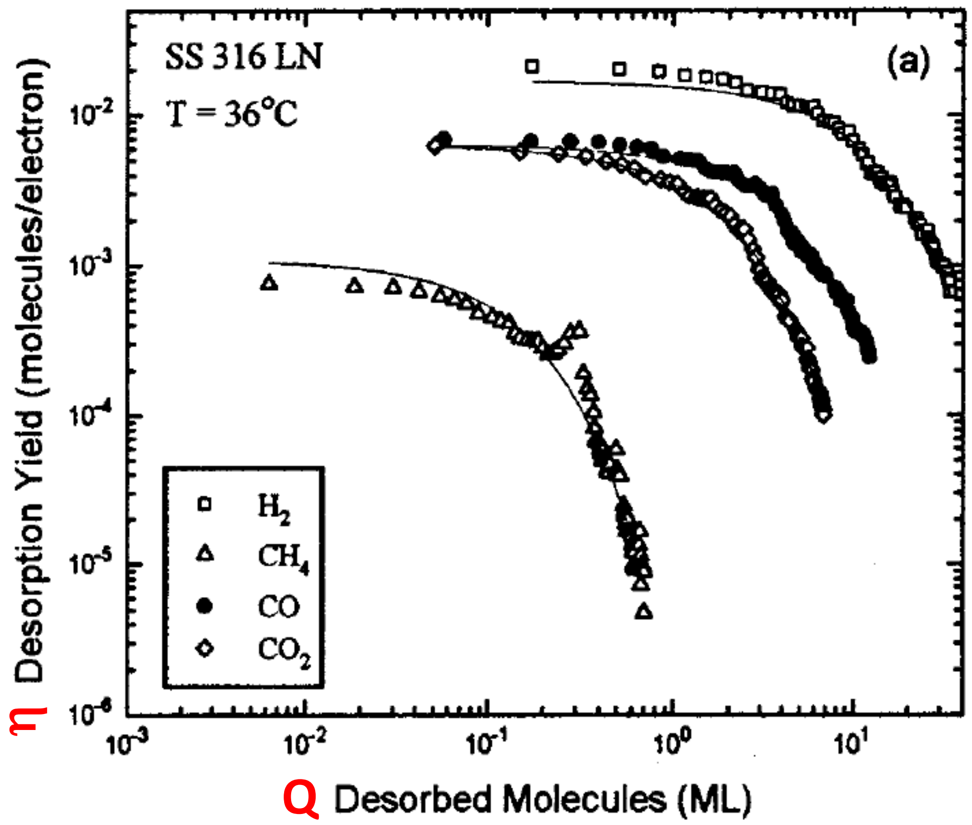




F. Billard, N. Hilleret, G. Vorlaufer, CERN, Vacuum Technical Note 00-32

Gas load: ESD, selected case 2

AISI 316 LN cleaned following CERN recipes,
baked *in situ at 150°C for 24 h* + *300°C for 2 h*.



The desorbed quantity of H_2, CO and CO_2 is much larger than one monolayer.

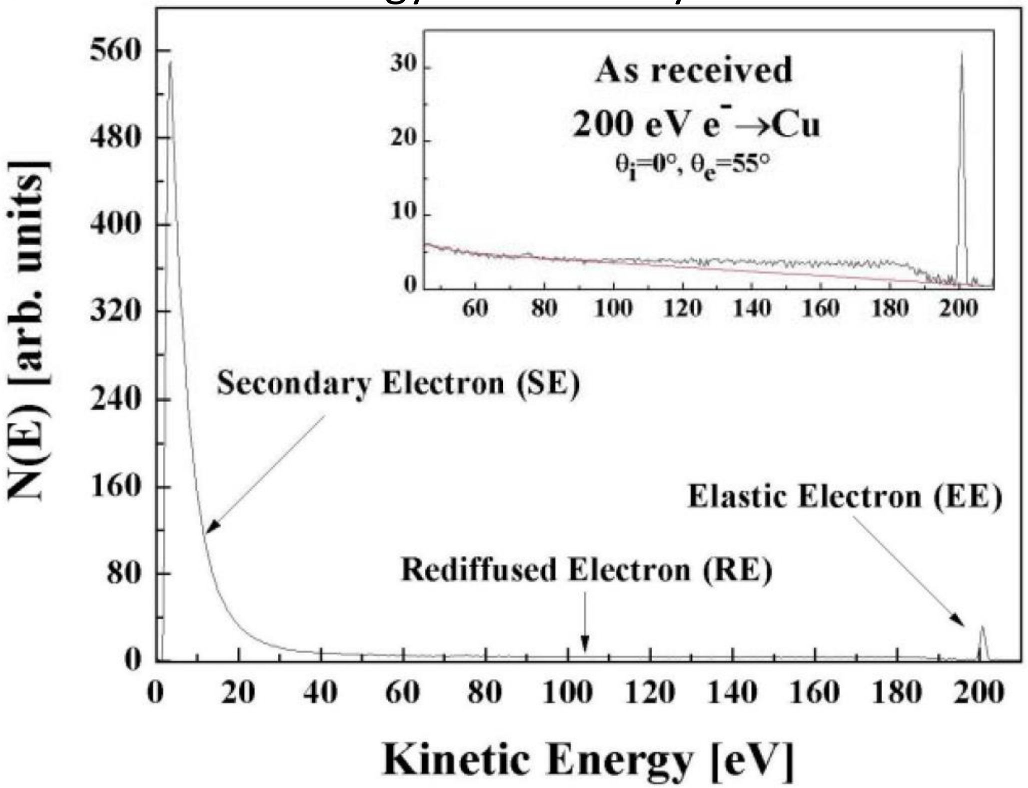
1 ML of $H_2 \approx 2\text{x}10^{15}$ molecules cm^{-2}

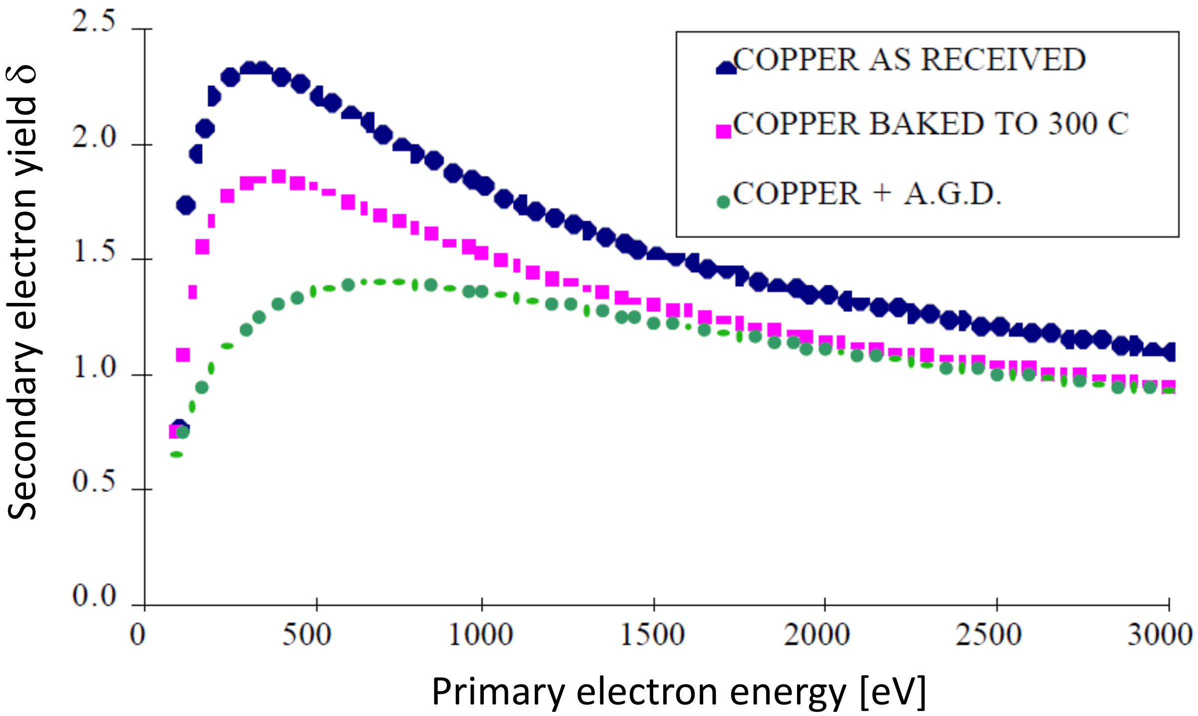
$$\eta = \eta_0 e^{-\frac{Q}{Q_0}}$$

J. Gómez-Goñi and A. G. Mathewson, J. Vac. Sci. Technol. A 15, 3093 (1997)

Electron multipacting: Secondary Electron Yield (SEY)

Energy of secondary electrons

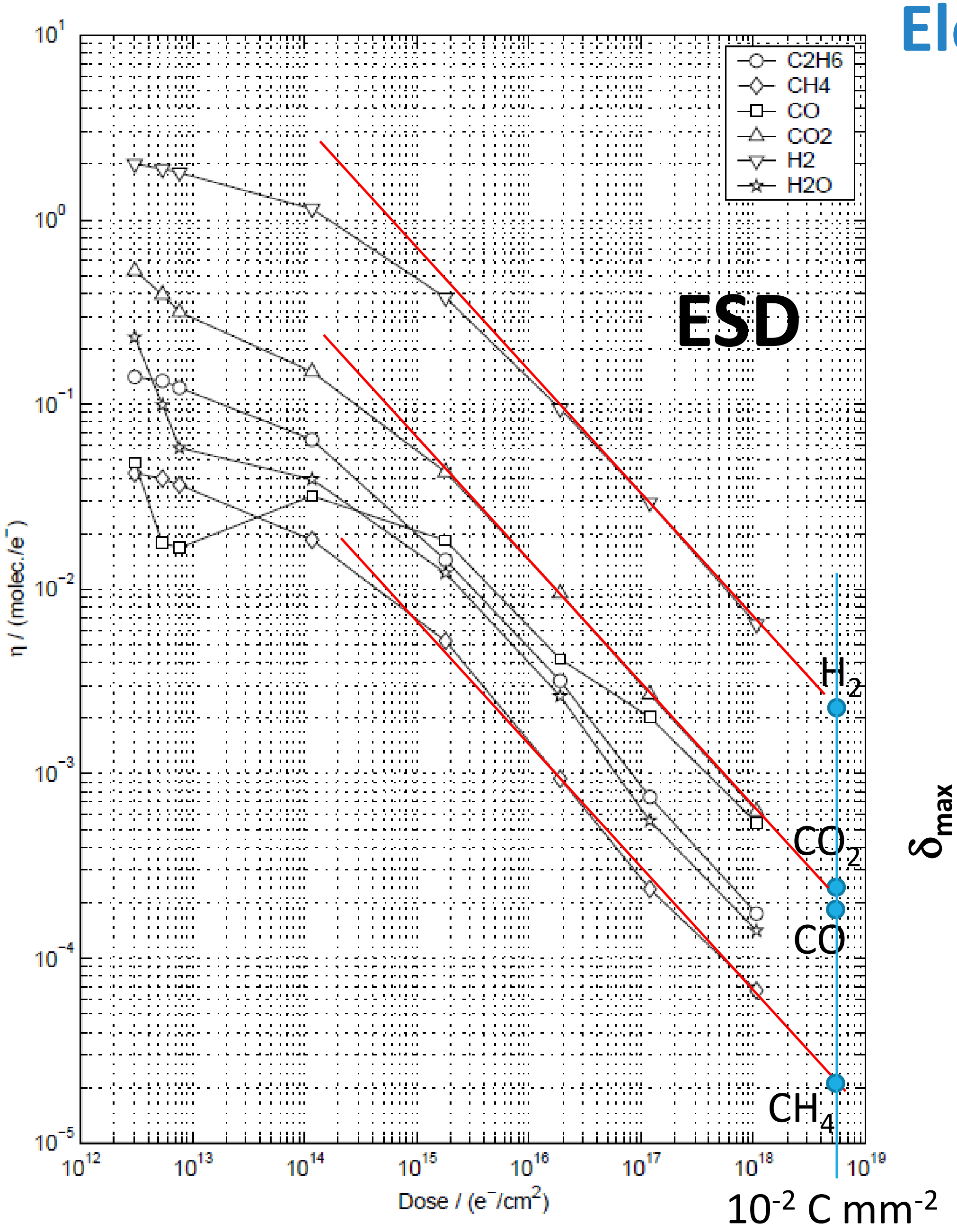




D. R. Grosso et al., Proc. of EPAC08, p. 1619, Genova, Italy

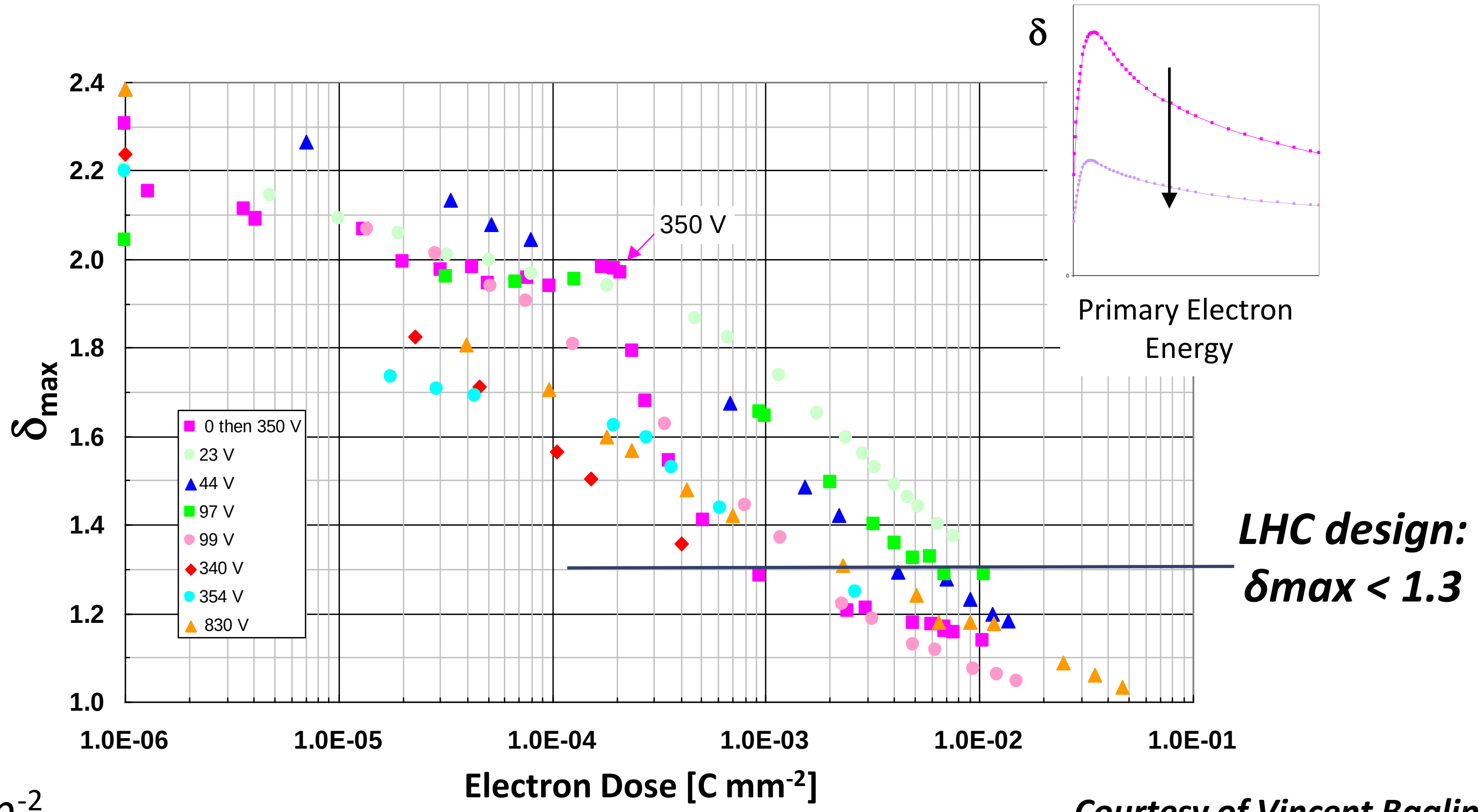
V. Baglin et al., Proc. of EPAC 2000, p. 217, Vienna, Austria

Electron multipacting: SEY, beam scrubbing



10^{-3} to 10^{-2} C/mm² are required to fulfil the LHC design: δ_{MAX}<1.3

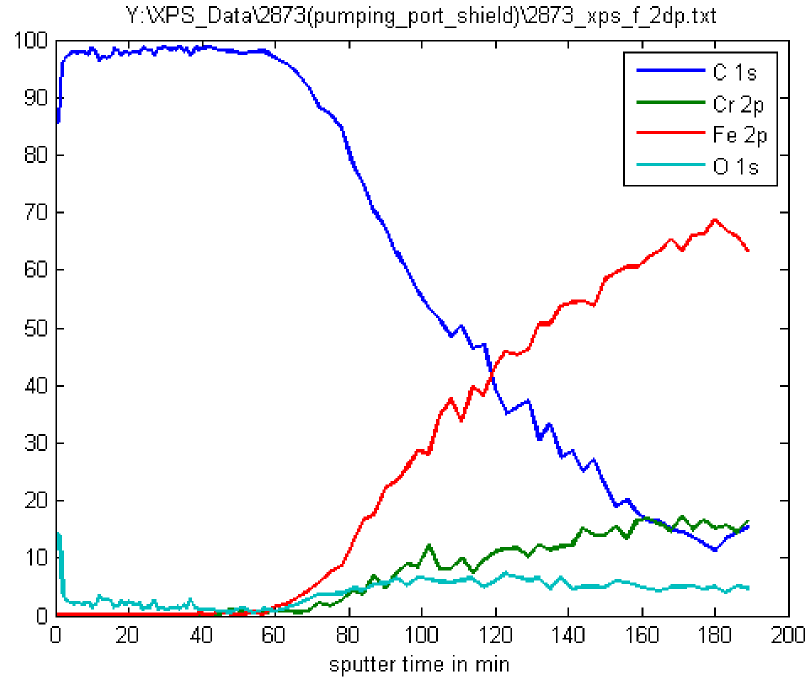
D=10^{-2} C mm^{-2}
ESD→ ≈10^3 reduction
SEY→ ≈ 50% reduction

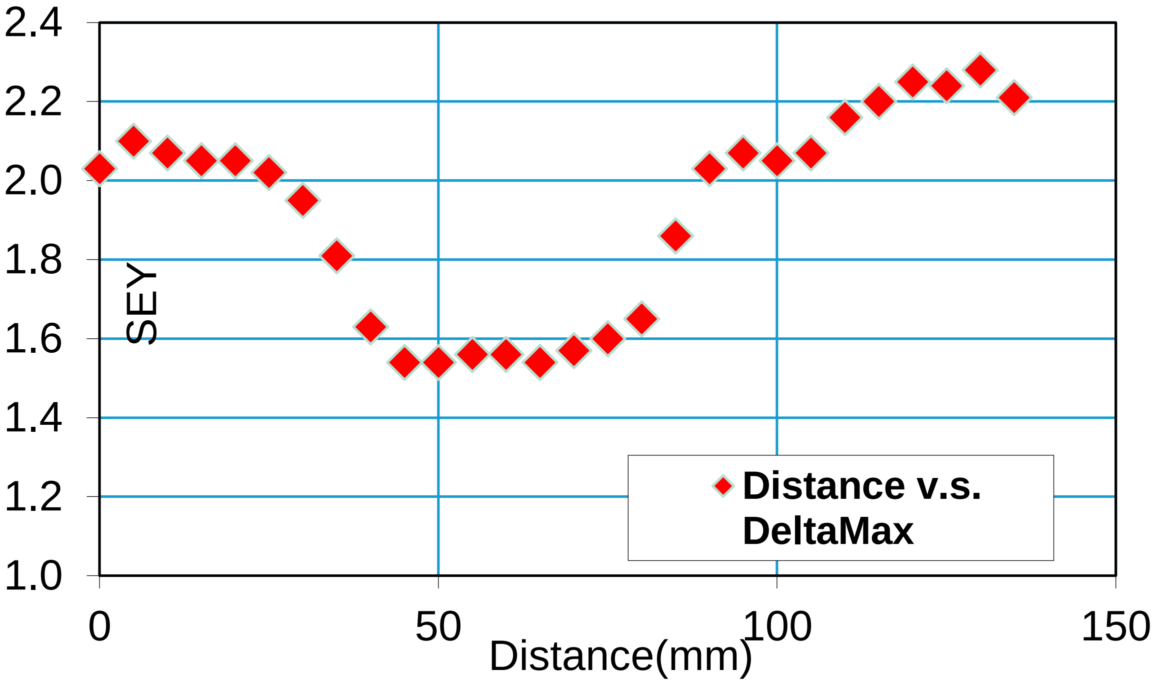


Courtesy of Vincent Baglin

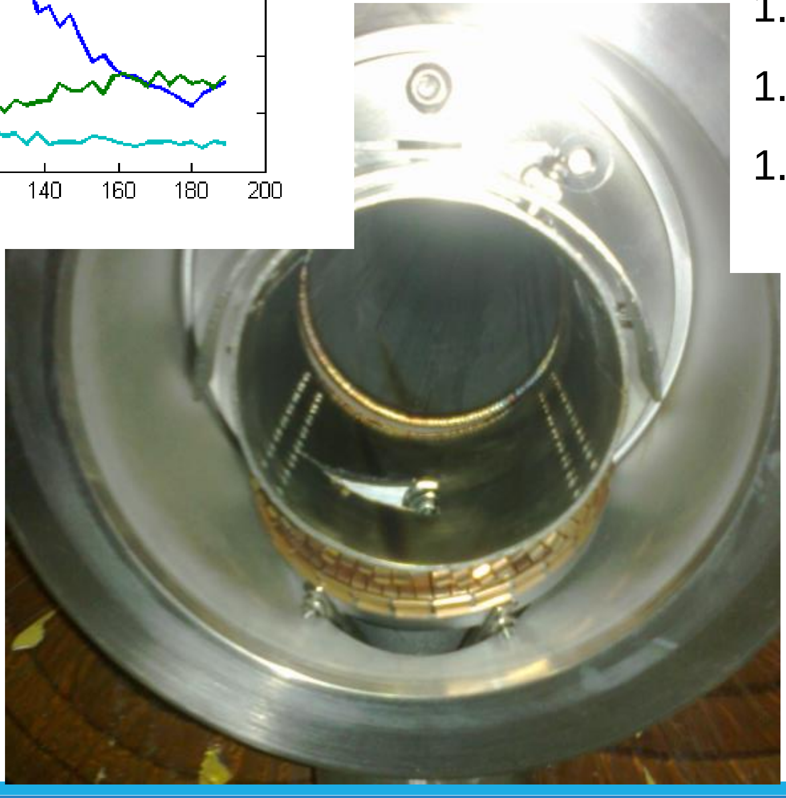
Electron multipacting: SEY, beam scrubbing

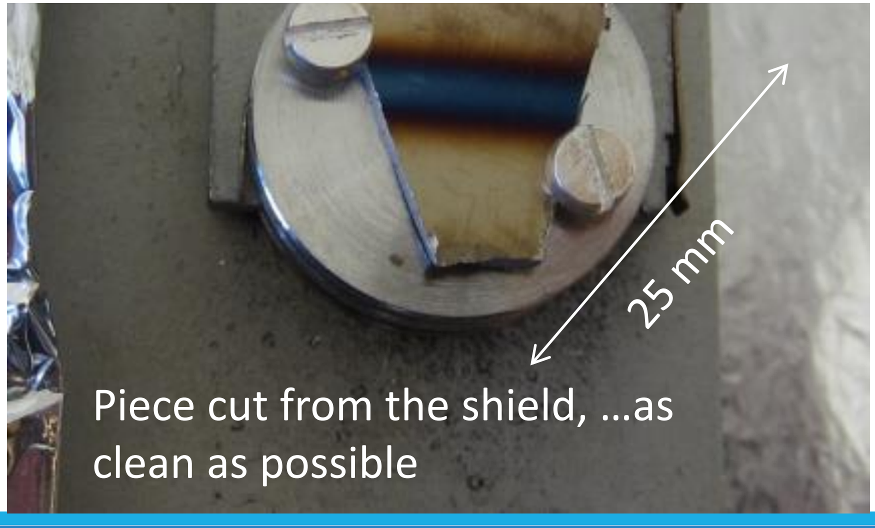
Courtesy of Mauro Taborelli





Dark stripe ⟹ Thick Carbon Layer





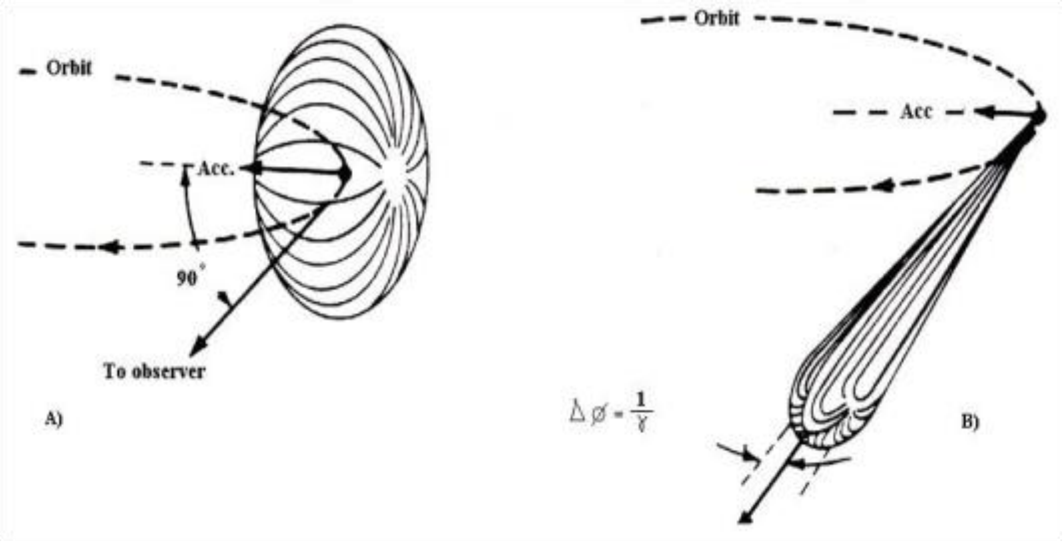
Piece cut from the shield, …as clean as possible

Gas load: Photon Stimulated Desorption (PSD)

Synchrotron emission is **strongly beamed** along the direction of motion, which is perpendicular to the acceleration.

The emission is concentrated into an angle of the order of **2/γ rad** along the direction of motion:

$$\gamma = 1/\sqrt{1-(v/c)^2} = E/mc^2$$



Gas load: PSD, power

A particle of charge 'e', energy E and rest mass m_0, moving on a circular orbit (radius ρ) radiates electromagnetic radiation with the following power P_{rad}:

$$P_{rad} = \frac{e^2 c}{6\pi\varepsilon_0 \left(m_0 c^2\right)^4} \frac{E^4}{\rho^2}$$

where ε_0 and c are the vacuum permittivity and the speed of light, respectively.

The emitted power depends strongly on the **beam energy,** the **radius of the bent trajectory**, and **the mass of the charged particle.**

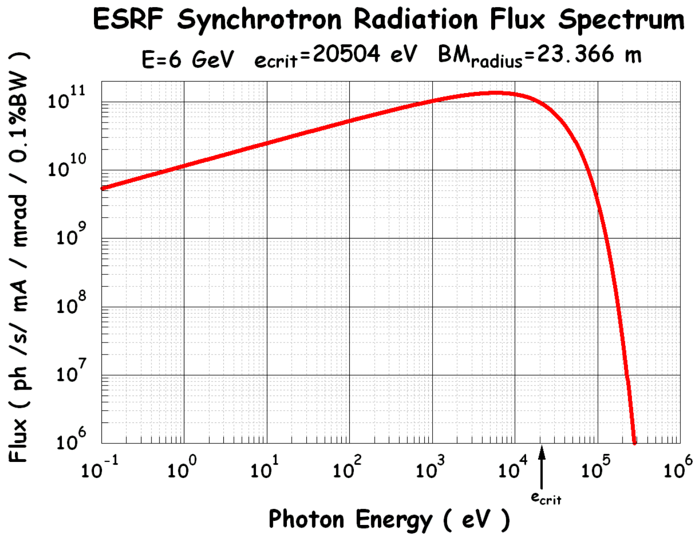
Consequently, **electrons emit much more synchrotron radiation power than protons** for the same bending radius and energy:

$$\frac{\left(P_{rad}\right)_{electrons}}{\left(P_{rad}\right)_{protons}} = \left(\frac{m_p c^2}{m_e c^2}\right)^4 = 1.13\times 10^{13}$$

Gas load: PSD, critical energy

Synchrotron radiation from bending magnets has a **very broad energy spectrum**, which is characterised by the **critical energy ε_C**:

$$\varepsilon_c = \frac{3}{2}\frac{\hbar c}{\rho}\gamma^3 = \frac{3\hbar c}{2(mc^2)^3}\frac{E^3}{\rho}$$

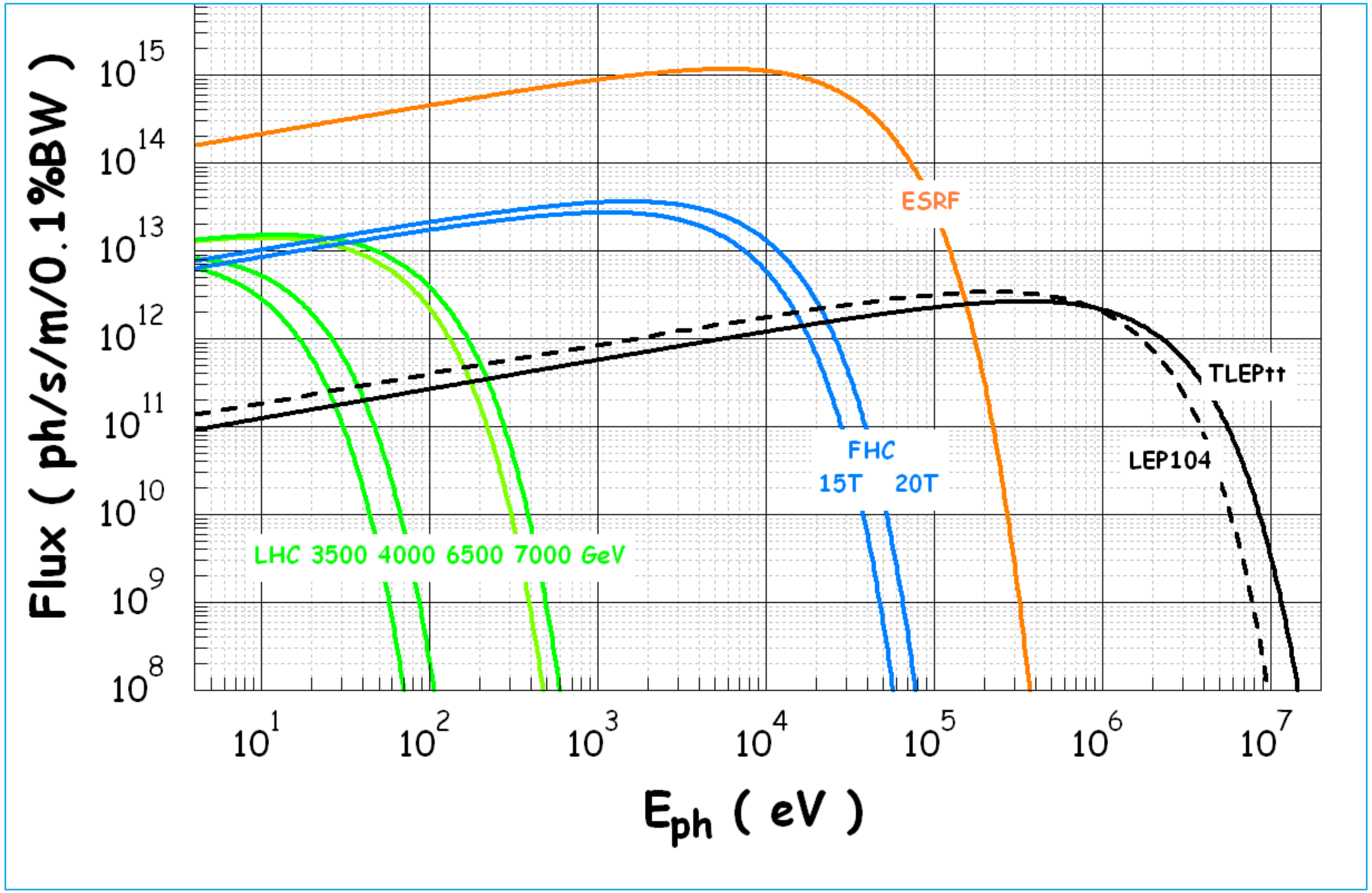


The critical energy subdivide the photon spectrum in two parts of equal emitted power.

For electrons $\varepsilon_c[KeV] = 0.665 \times E^2[GeV^2] \times B[T]$

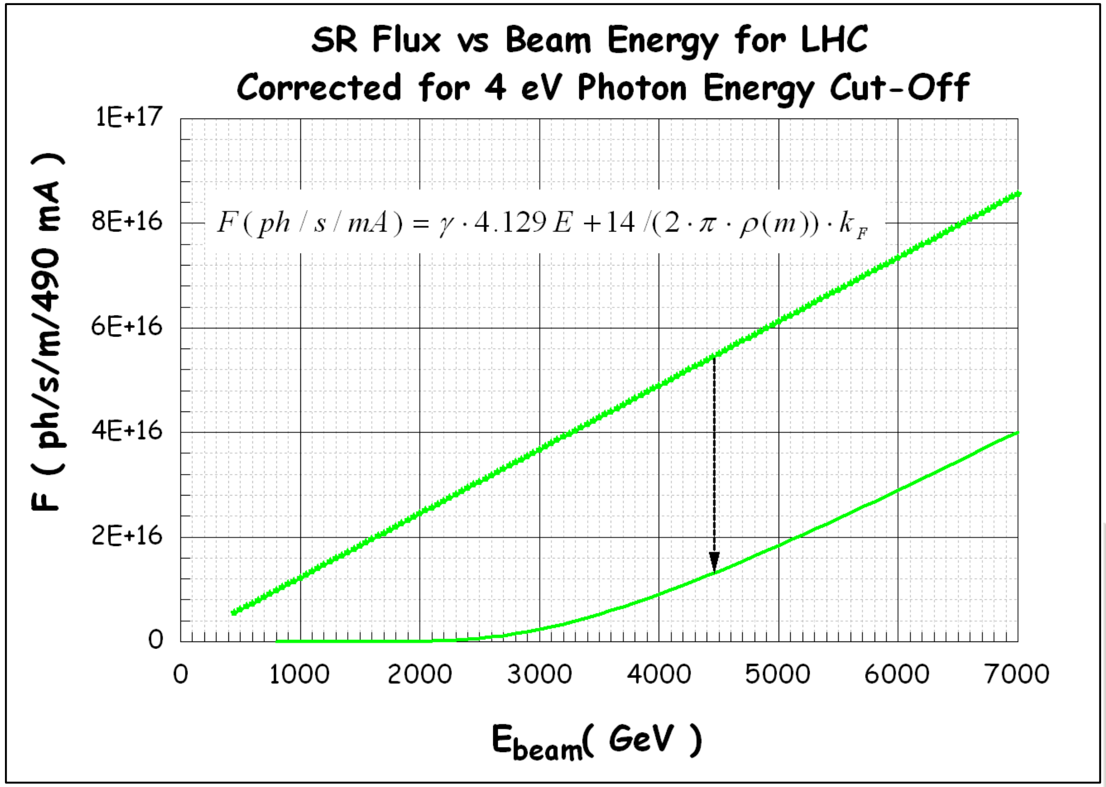
For protons $\varepsilon_c[KeV] = 1.1 \times 10^{-10} \times E^2[GeV^2] \times B[T]$

Gas load: PSD, spectra



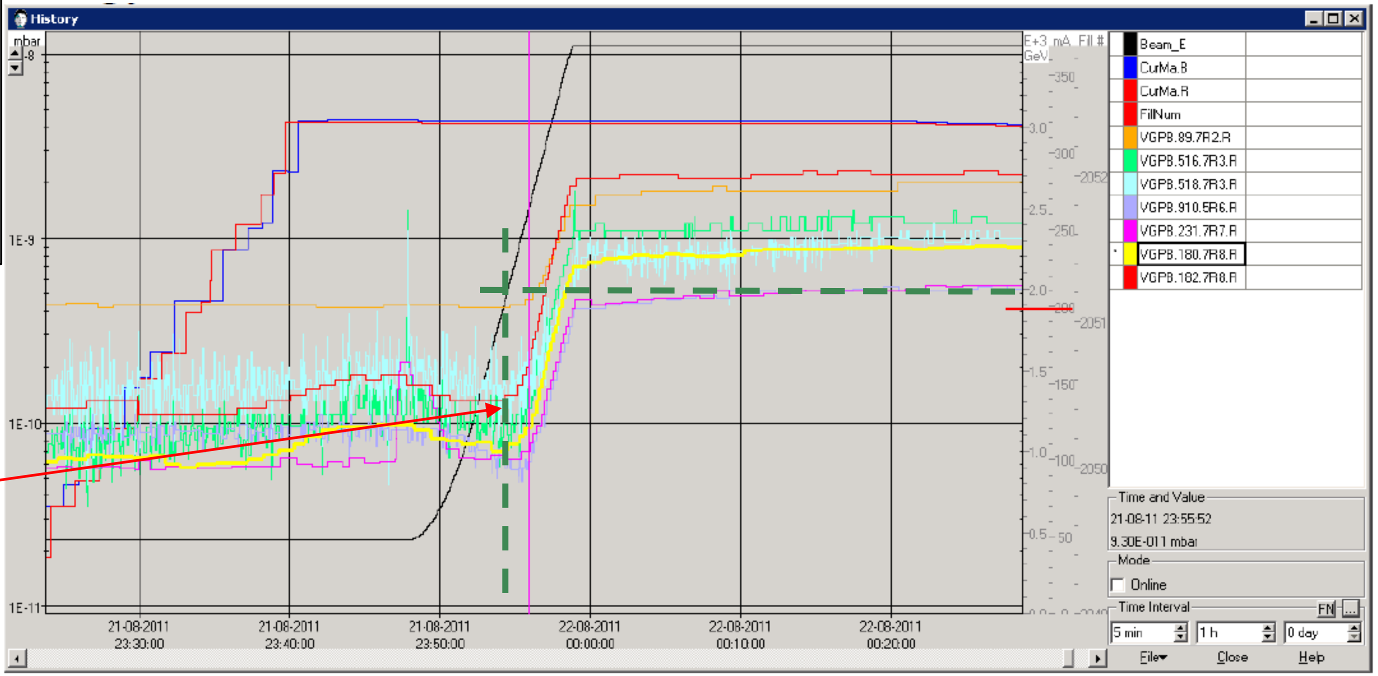
Courtesy of Roberto Kersevan

Gas load: PSD, cut-off energy



Courtesy of Roberto Kersevan

Correction for the **cut-off energy of the photons**: 4 eV (work function); below this value there is no photoelectron emission and no SR-induced desorption.



Note the onset of pressure rise at 2 TeV, as seen by the vacuum gauges in the LHC **during energy ramp.**

Gas load: PSD, impinging photons

It can be shown that the number of emitted photon per unit time:

$$\dot{N} = \frac{15\sqrt{3}}{8}\frac{P_{rad}}{\varepsilon_c}$$

$$\dot{N} = \frac{P_{rad}}{\langle\varepsilon\rangle} \rightarrow \langle\varepsilon\rangle = \frac{8}{15\sqrt{3}}\varepsilon_c$$

Mean photon energy: max of the distribution

For electrons

$$\dot{N} = 8.08\times10^{17}\, I[mA]E[GeV]$$

The linear flux, i.e. the emitted photons per second and meter, is given by

For electrons

$$\frac{d\dot{N}}{ds} = 1.28\times10^{17}\,\frac{I[mA]E[GeV]}{\rho[m]}$$

Gas load: PSD, LHC

For both electron and proton beams

$$\frac{d\dot{N}}{ds} \approx 6.57\times10^{13} \frac{\gamma}{\rho[m]} I[mA] \; \frac{\text{photons}}{\text{m}\cdot\text{s}}$$

$$\frac{dP}{ds} \approx 9.6\times10^{-13} \frac{\gamma^4}{\rho^2[m^2]} I[mA] \; \frac{\text{W}}{\text{m}}$$

For LHC:

- γ = 7460.52
- ρ = 2804.95 m
- I = 490 mA

$$\frac{d\dot{N}}{ds} \approx 8\times10^{16} \; \frac{\text{photons}}{\text{m}\cdot\text{s}}$$

$$\frac{dP}{ds} \approx 0.18 \; \frac{\text{W}}{\text{m}}$$

For FCC-hh (50 TeV, 15 T):

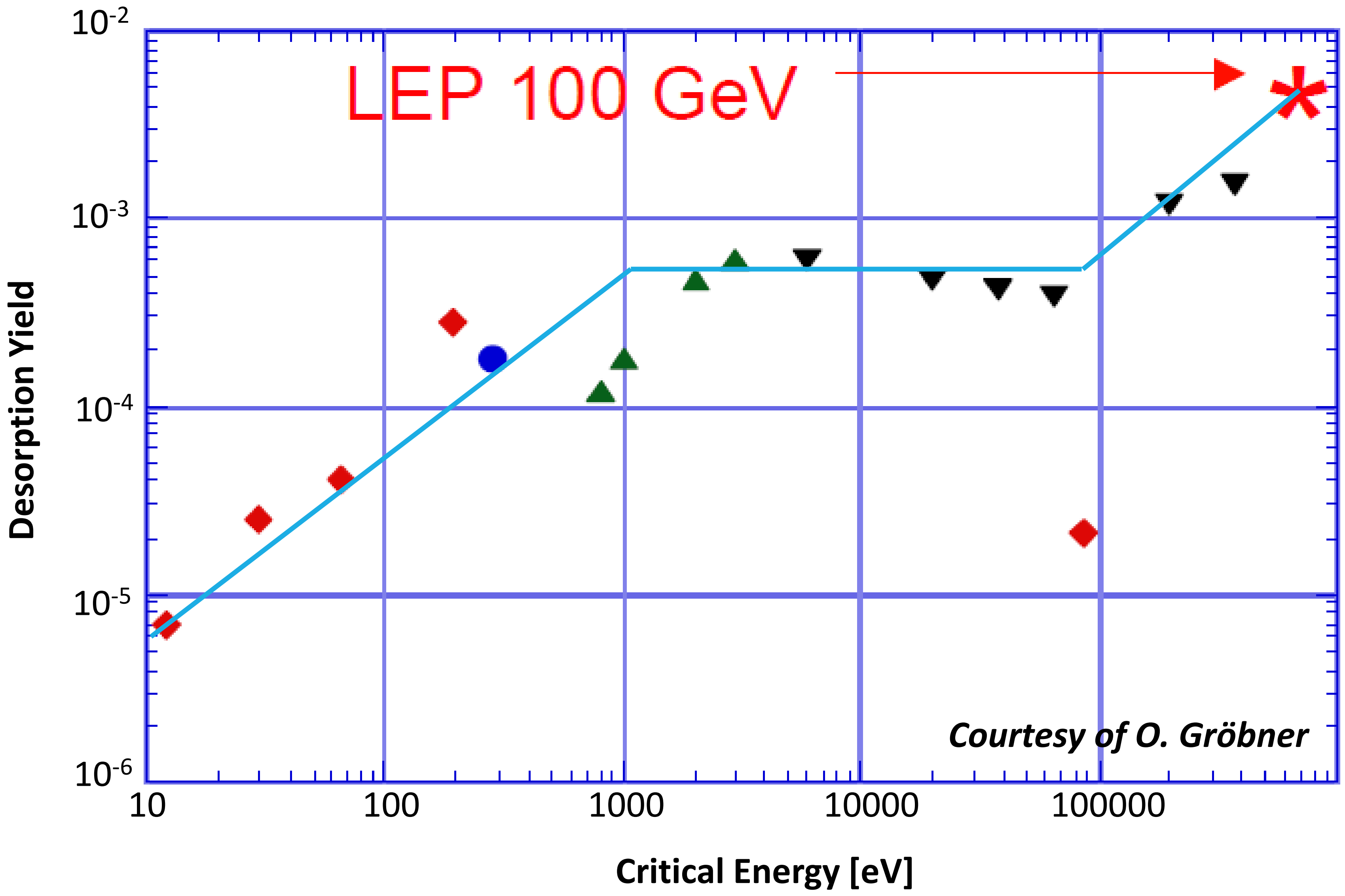
- γ = 53289
- ρ = 11118.8 m
- I = 490 mA

$$\frac{d\dot{N}}{ds} \approx 1.5\times10^{17} \; \frac{\text{photons}}{\text{m}\cdot\text{s}}$$

$$\frac{dP}{ds} \approx 30.7 \; \frac{\text{W}}{\text{m}}$$

$$\frac{dQ}{ds} = \eta_{ph} \frac{d\dot{N}}{ds} \left[\frac{molecule}{\text{m}\cdot\text{s}}\right]$$

Gas load: PSD, dependence on critical energy



Above 60 keV, the **Compton scattering** plays a predominant effect in the interaction of photons with the material of the vacuum chamber.

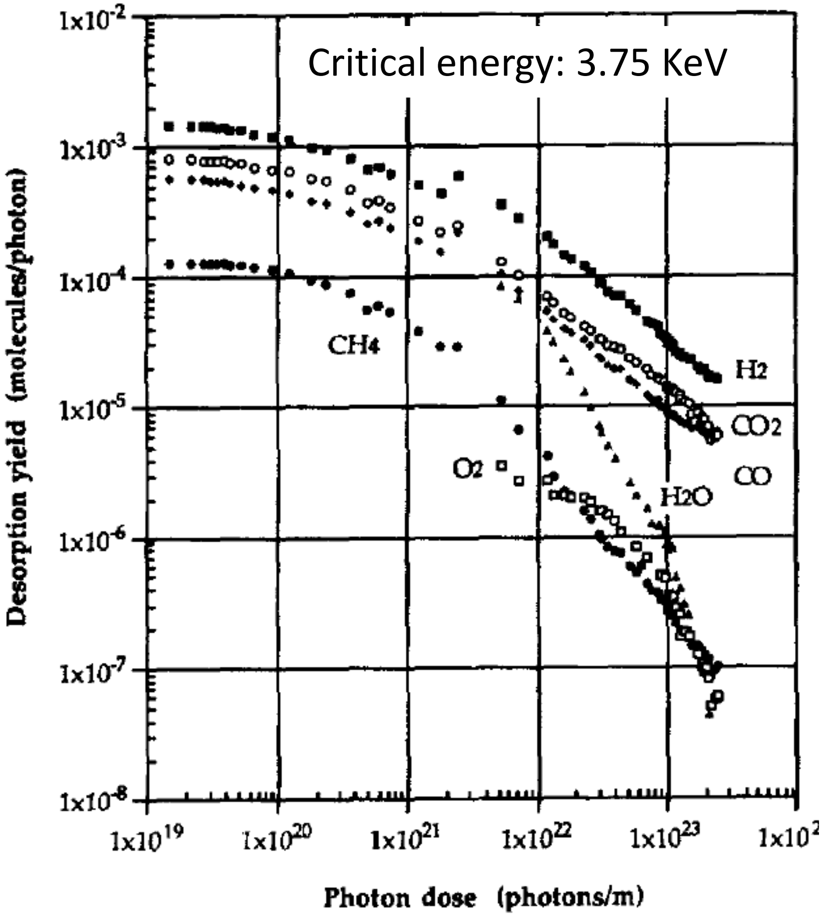
The high number of energetic recoil electrons and scattered photons increase the desorption yields.

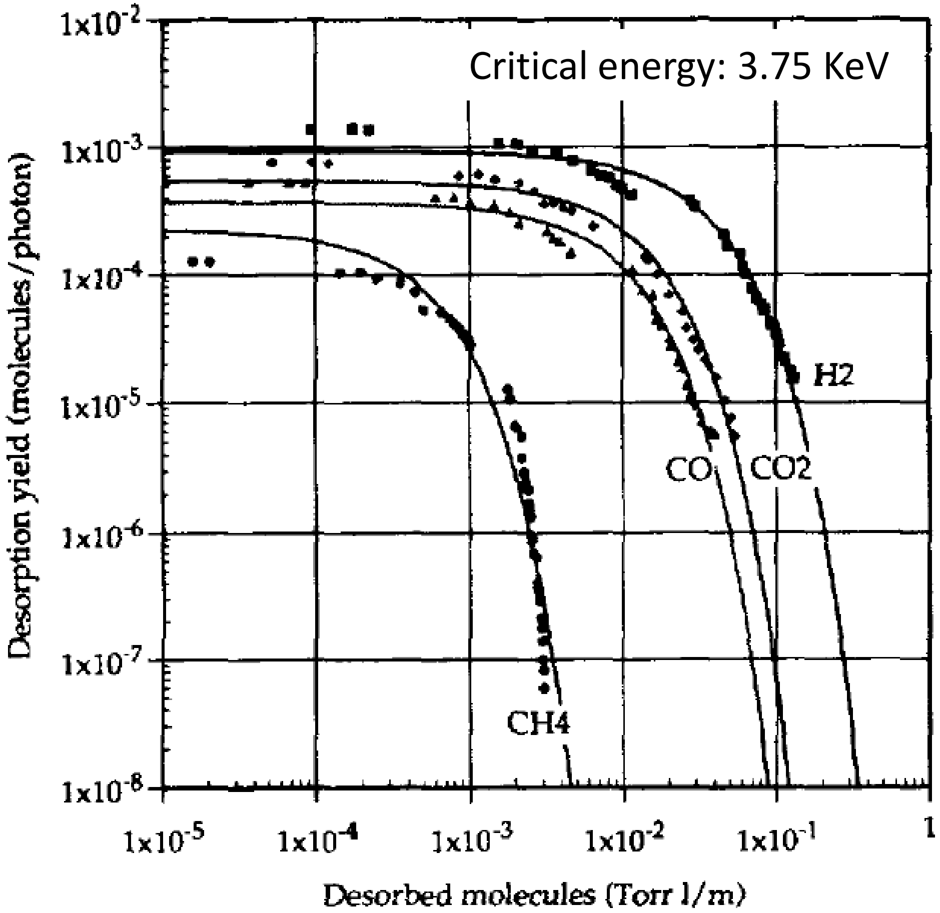
Gas load: PSD, dependence on dose

For doses higher than 10^{20} photons/m doses, η_{ph} varies as a **power law function of the dose**:

$$\eta_{ph} \propto D^{-\alpha}$$

J. Gomez-Goñi et al, J. Vac. Sci. Technol. A 12, 1714 (1994)





OFHC copper, baked in situ at 150°C for 24 h

Gas load: PSD, dependence on incidence angle

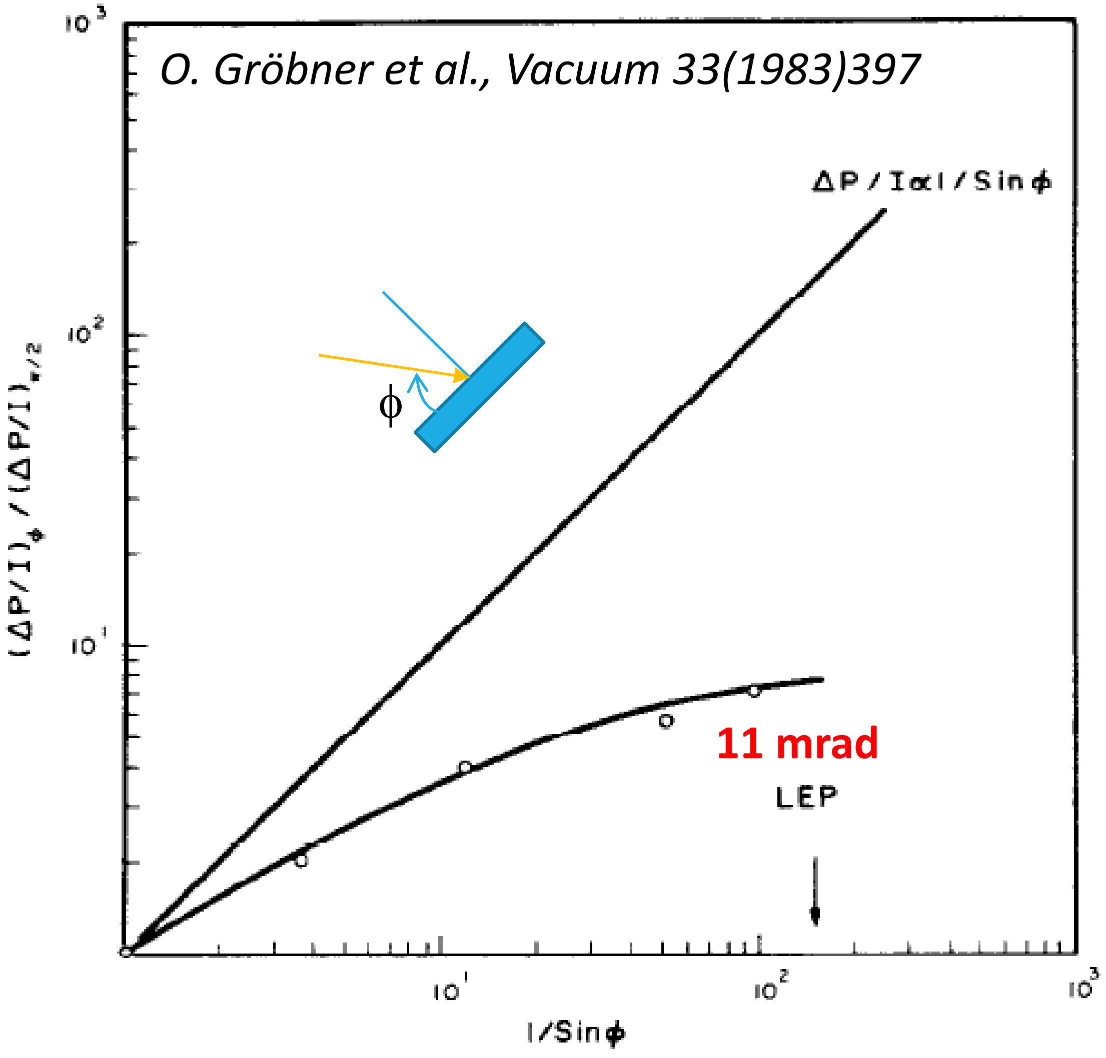


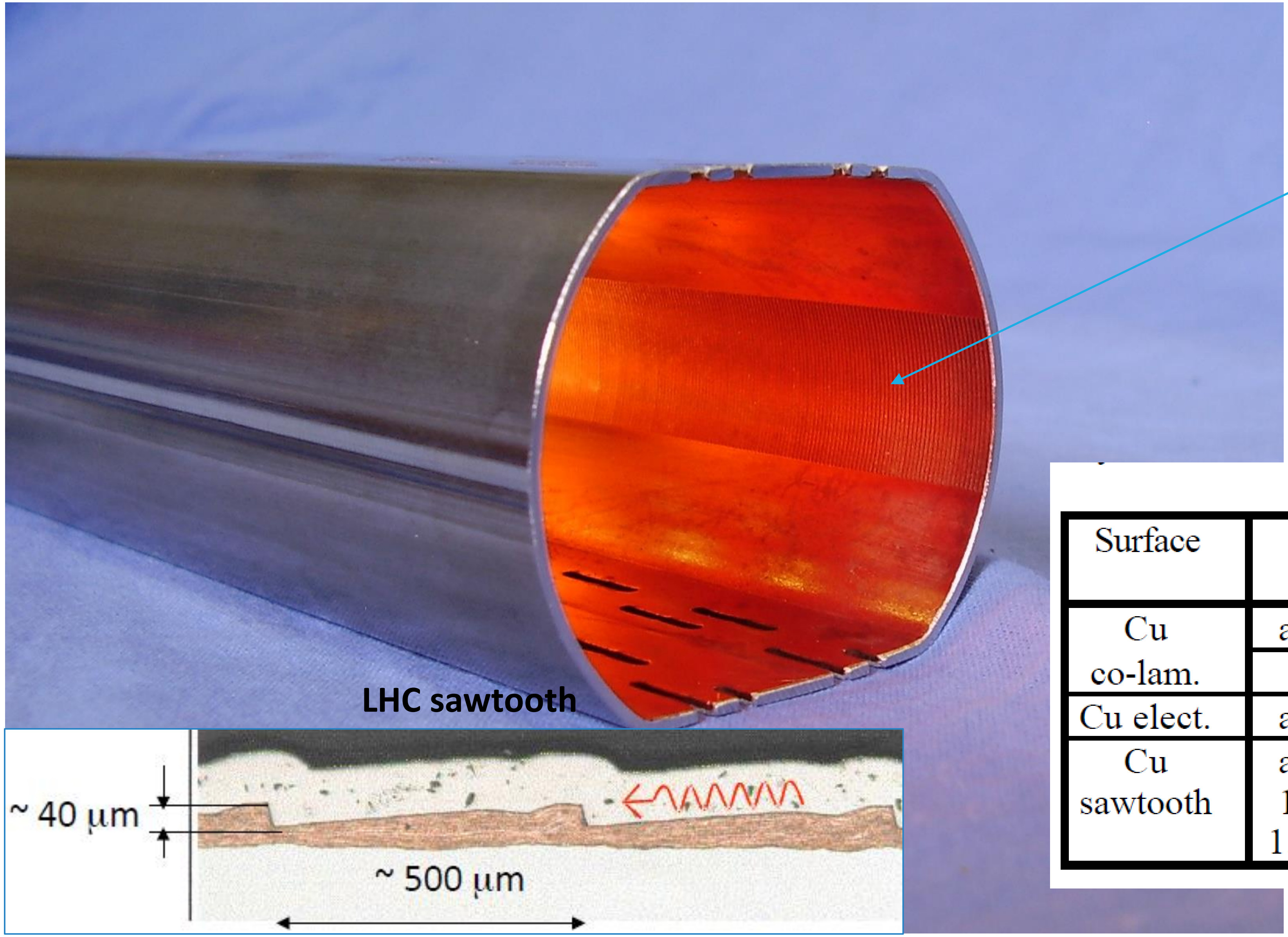
Figure 11. The dependence of the total specific pressure rise on the glancing angle of incidence at a beam energy of 1.72 GeV.

Photo-desorption yields depend on the **incidence angle**

The photodesorption yield is higher when the angle of incidence is lower.

In most of the accelerators the incidence is at grazing angle.

Gas load: PSD, LHC



In the LHC beam screen, the inner wall was machined so that photons impinge nearly perpendicularly onto the copper layer.

Desorption yield, photoelectron yield and photon reflectivity are reduced.

11 mrad

Surface	Status	45 eV R (%)	45 eV Y* (e/ph)	194 eV R (%)	194 eV Y* (e/ph)
Cu co-lam.	as-received	80.9	0.114	77.0	0.318
	air baked	21.7	0.096	18.2	0.180
Cu elect.	as-received	5.0	0.084	6.9	0.078
Cu sawtooth	as-received	1.8	0.053	-	-
	150°C, 9h	1.3	0.053	1.2	0.052
	150°C, 24h	1.3	0.040	1.2	0.040

V. Baglin et al., EPAC 1998

Gas load: Ion Stimulated Desorption (ISD)

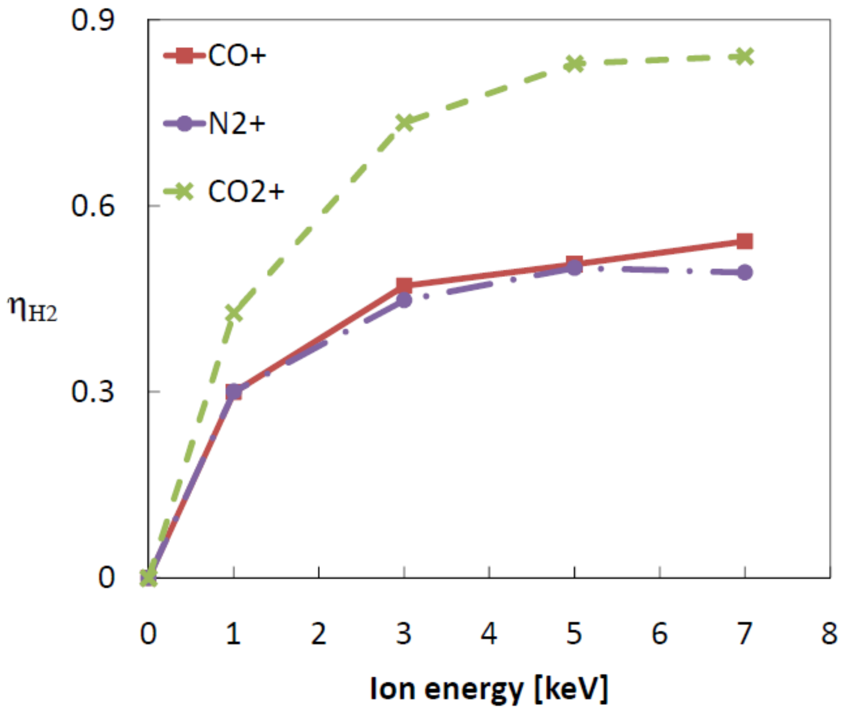
There are two sources of energetic ions:

1. Beam particles may collide with the **residual gas** and create ions (H_2^+, CH_4^+, CO^+, CO_2^+, etc.). If the beam is positively charged, the ions are accelerated by the beam potential and collide on the nearby walls with energy between **1 eV to several KeV**. The collisions result in gas desorption.

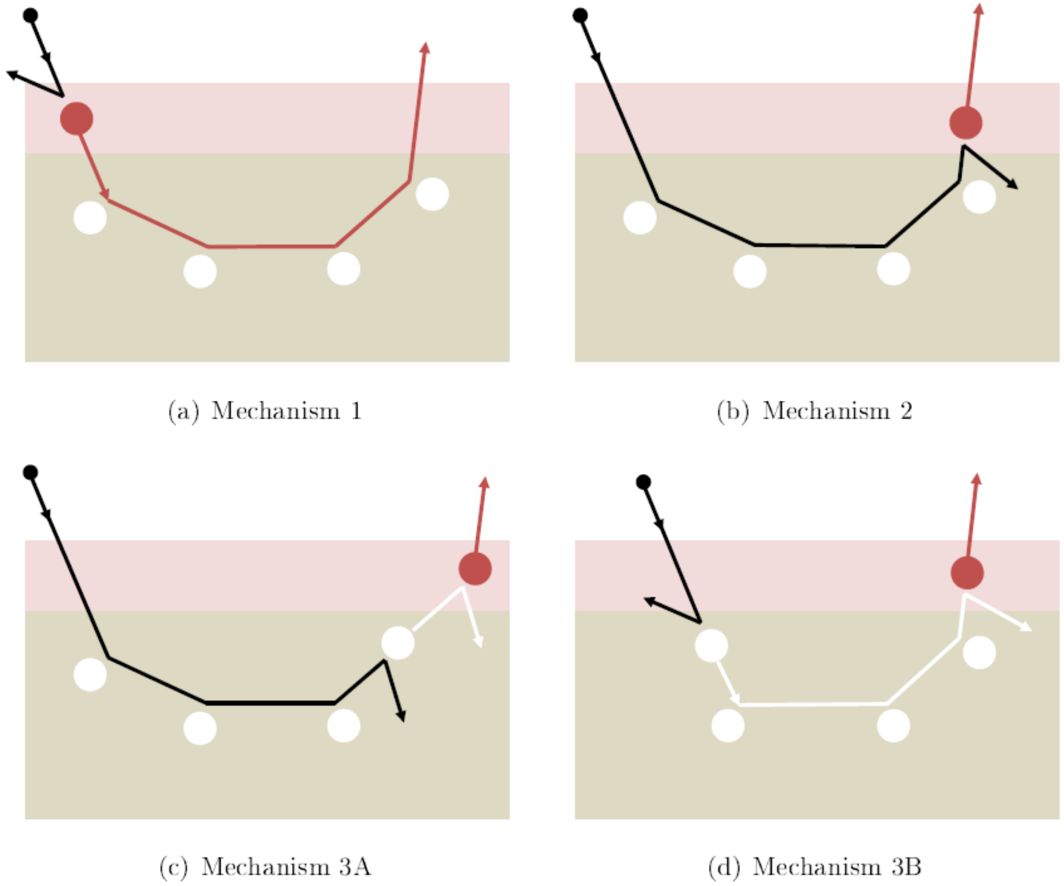
2. When **heavy ions are accelerated**, beam losses may lead to collision of high-energy heavy ions with the wall of the vacuum system. Typical ions are Pb^{53+}, U^{73+}, and Ar^{10+}. Experimental studies have been carried out with beam energy in the range from **1 MeV/nucleon to 100 GeV/nucleon**. The desorption yields may be orders of magnitude higher than those for residual-gas ions.

Gas load: ISD, residual-gas ions

Ions are more effective in desorbing gas than electrons. Typical η_i values for baked copper and ion energy of about 1 KeV are about **1** for H_2 and CO; 5 and 10 times lower for CO_2 and CH_4, respectively.

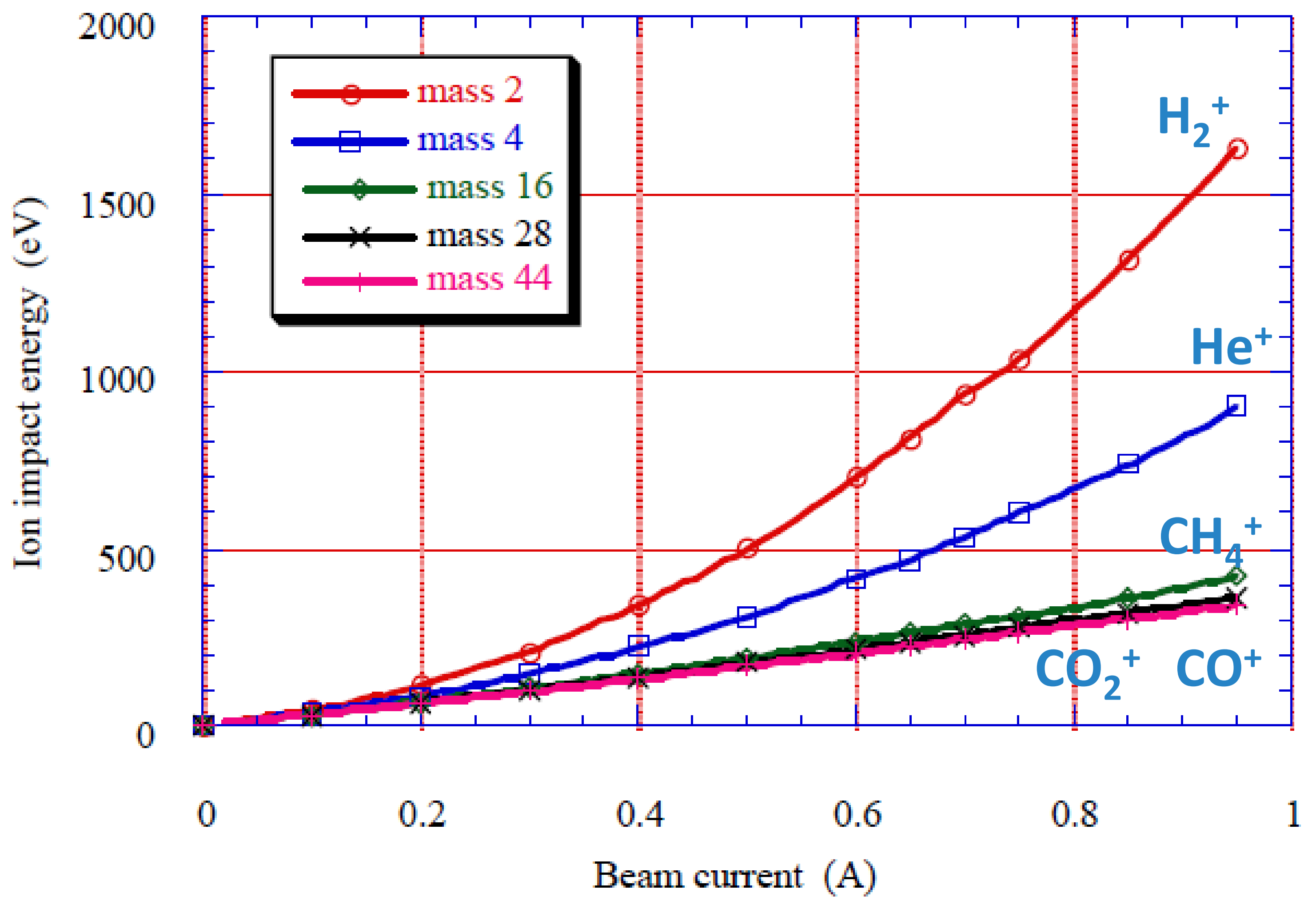


G. Hulla, PhD Thesis, Technischen Universität Wien, 2009



Gas load: ISD, residual-gas ions

Ion impact energy in LHC beam screen as a function of proton beam current



O. Gröbner, https://cdsweb.cern.ch/record/455985/files/p291.pdf

Gas load: ISD, residual-gas ions, conditioning

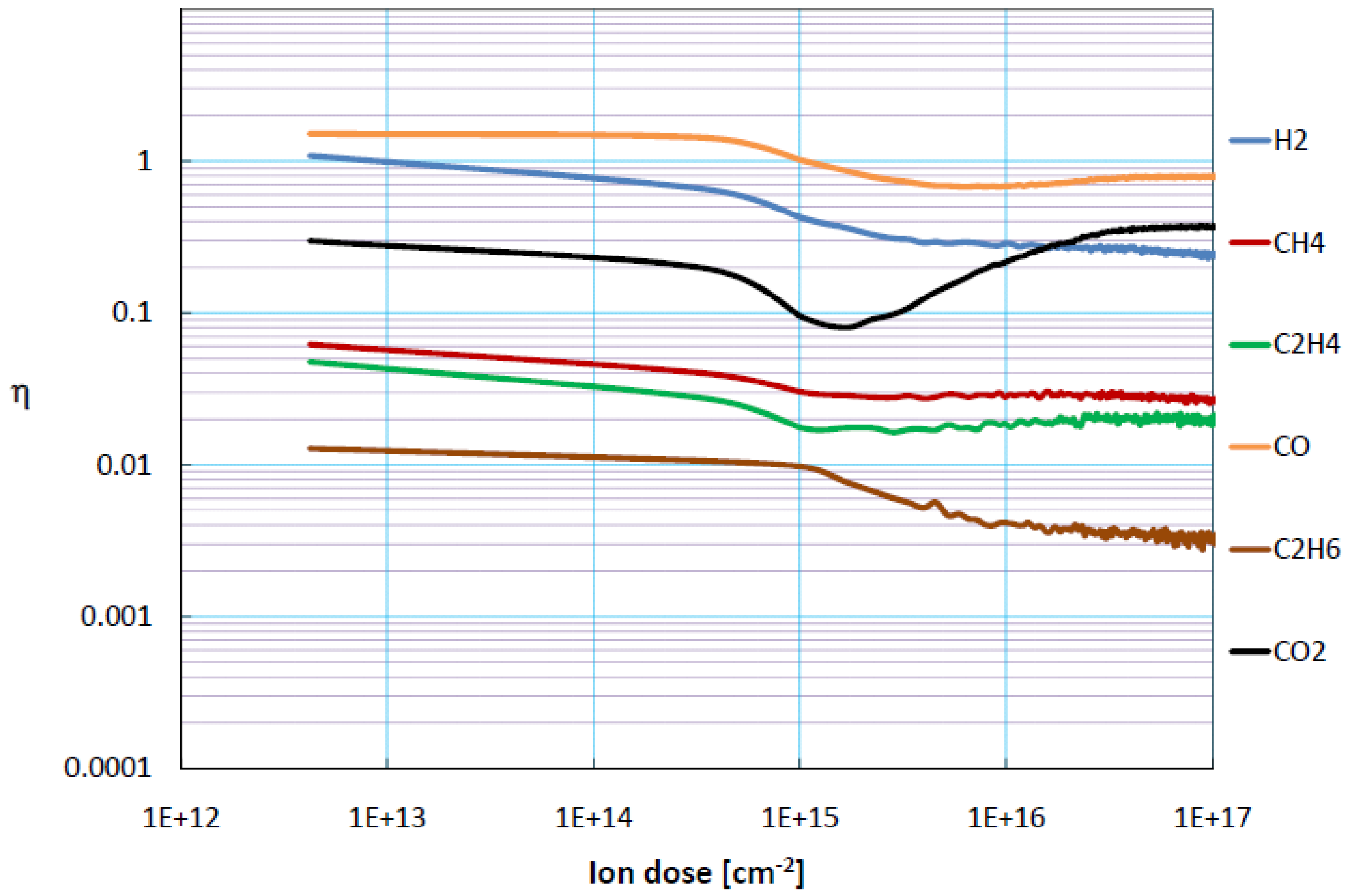


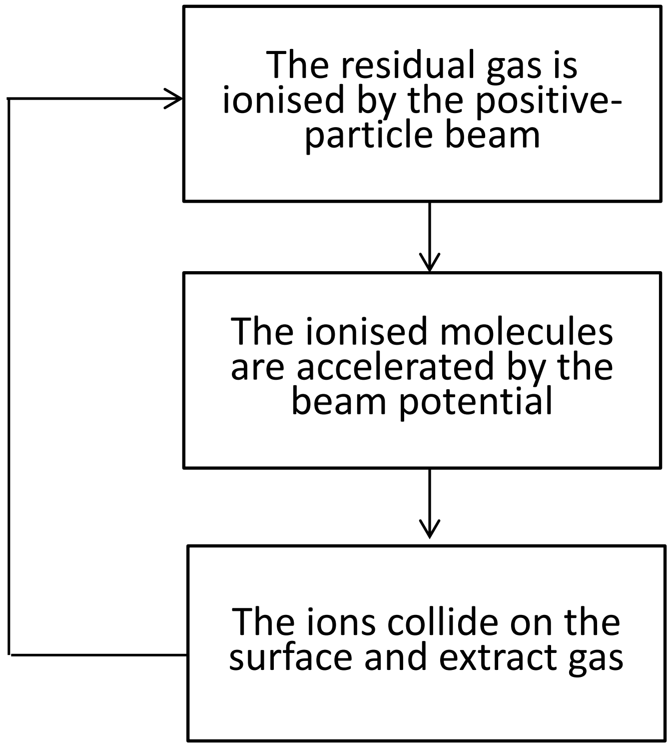
Figure 6.25: Dose dependance of 7keV CO^+-ions incident on copper.

G. Hulla, PhD Thesis, Technischen Universität Wien, 2009

Gas load: ISD, ion-induced pressure instability

Ion induces desorption can trigger a rapid pressure rise in vacuum chambers where positive beams circulate. This phenomenon was shown first at the CERN ISR when increasing the proton current to about 1 A.

The pressure rise is generated by a **positive feedback** process that can be depicted with the following block diagram.



Gas load: ISD, ion-induced pressure instability

Critical current:

$$I_c[A] = 10 \frac{S\left[\frac{\ell}{s \cdot m}\right] \cdot e[C]}{\eta_i \cdot \sigma_i\left[cm^2\right]}$$

Gas	σ_i [10^{-18} cm^2] 26 GeV	σ_i [10^{-18} cm^2] 7 TeV
H_2	0.22	0.37
He	0.23	0.38
CH_4	1.2	2.1
CO	1.0	1.8
CO_2	1.1	2.0
Ar	1.6	2.8

O. Gröbner, The LHC vacuum system
https://cdsweb.cern.ch/record/455985/files/p291.pdf

Example:

For an effective pumping speed of **100 l $s^{-1}m^{-1}$** and an ionisation cross section of **10^{-18} cm^2** (CO ionised by protons at 26 GeV), the critical current is about **160 A** if the desorption yield is 1.

For the **LHC** (**0.45 A**), the **critical pumping speed** is about **0.3 l s^{-1} m^{-1}**: there is more than a **factor 100 of margin**!

Mitigation

We have seen that :

- Stimulated desorption
- Secondary electron and photoelectron emission

are reduced by beam conditioning.

Other mitigation are available today:

- thin-film coating

- change of the surface morphology

- axial magnetic field
- clearing electrodes

Thin films

- NEG(*)
- TiN
- a-C

Surface morphology

- Grooves
- LESS(**)

(*) Non-Evaporable Getter

(**) Laser Engineered Surface Structures

Mitigation: TiN coating

- Already implemented in the SNS accumulator ring by BNL.
  - *P. He et al, Proceedings of EPAC 2004, p. 1804, Lucerne*

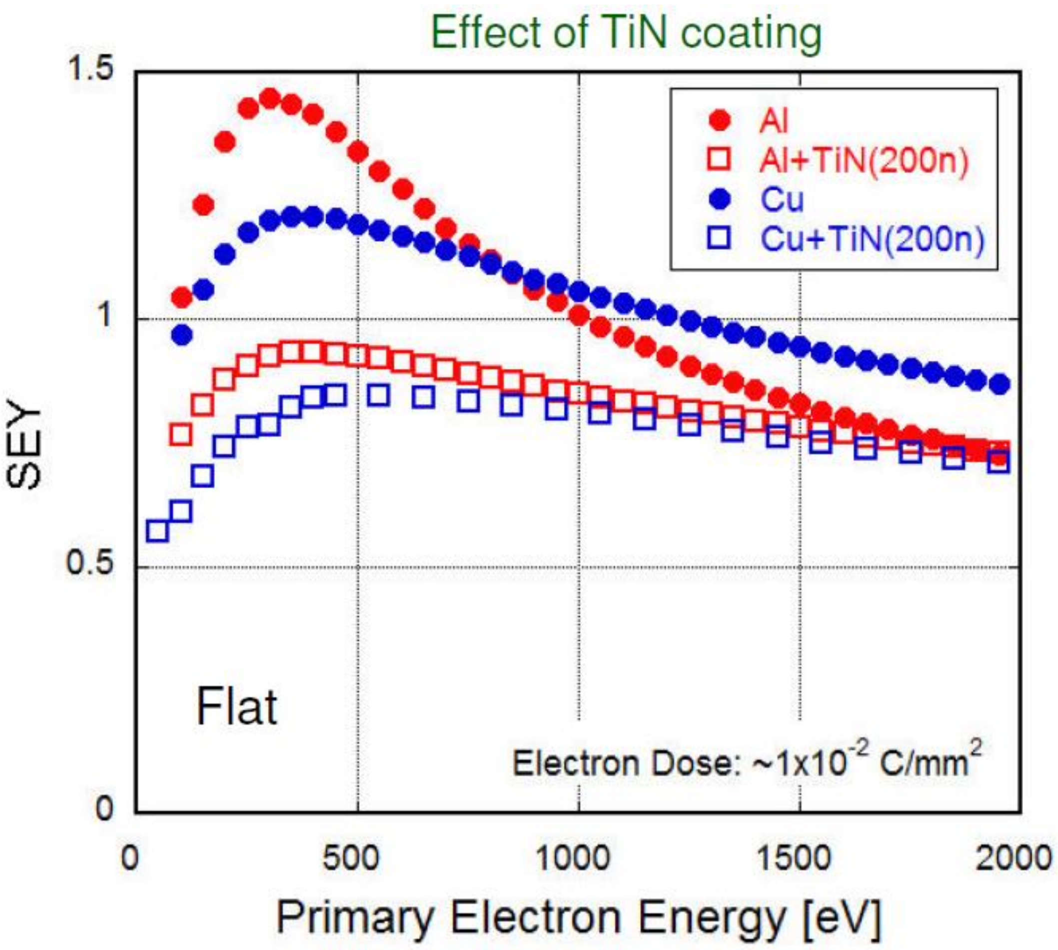
- Early papers:
  - *H. Padamsee and A. Jashi, J. of Appl. Phys. 50, 1112 (1979)*
  - *M.A. Allen and P.B. Wilson, Proceedings of the Ninth Int. Conf. on High Energy Accelerators, Stanford, 1974, p. 92*

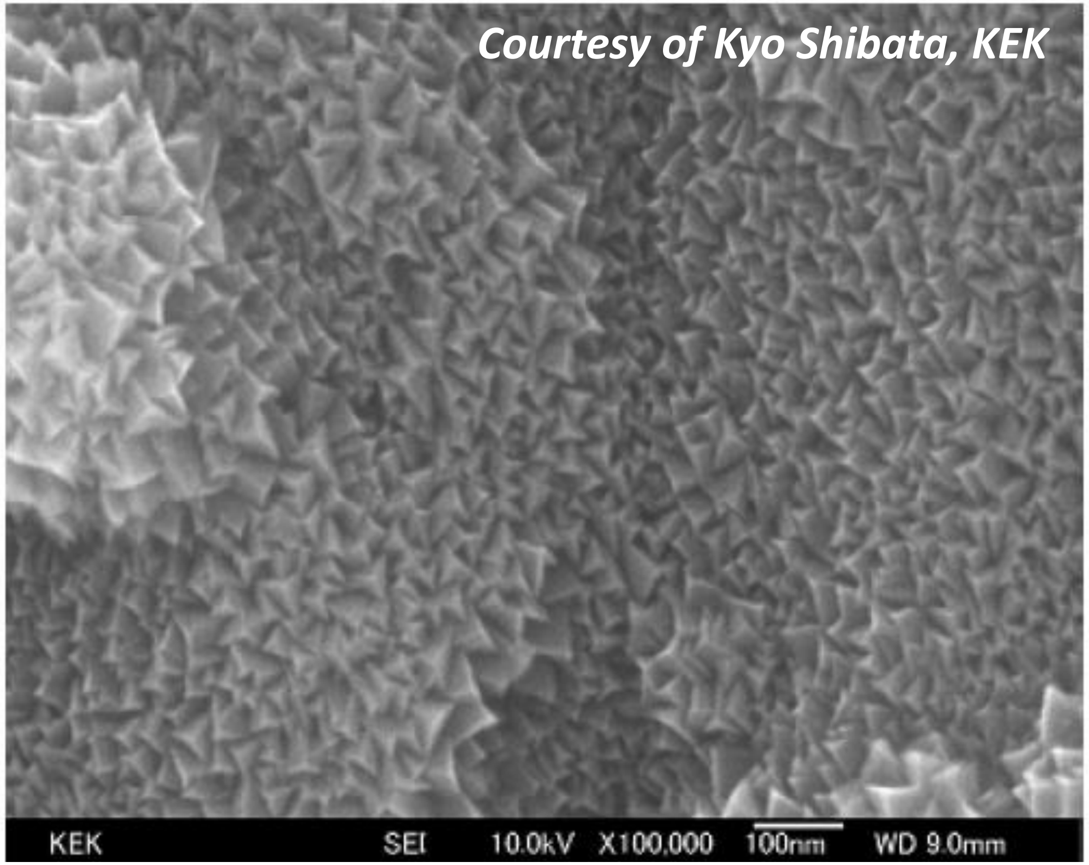
- Used as main ecloud mitigator in super-KEKB

Courtesy of Kyo Shibata, KEK

Mitigation: TiN coating

Courtesy of Y. Suetsugu, KEK (LER2010, CERN)



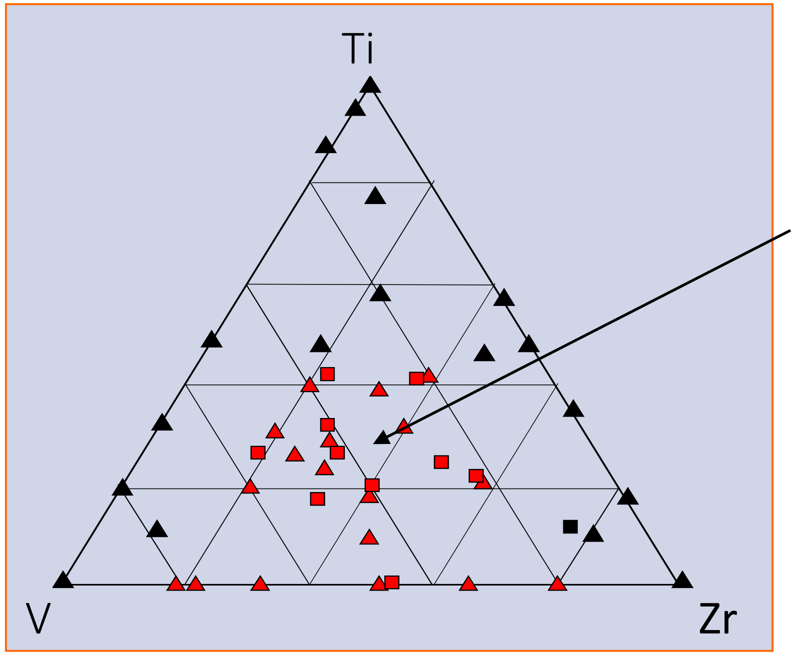


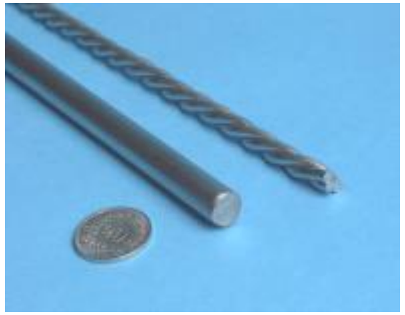
- The SEY of TiN can be reduced much faster than the one of bare Al alloys.
- The morphology of the film could have a crucial role in reducing the SEY.
- TiN is known to have also a lower photoelectron yield than traditional materials.

Mitigation: Ti-Zr-V coating

Coatings: Ti-Zr-V

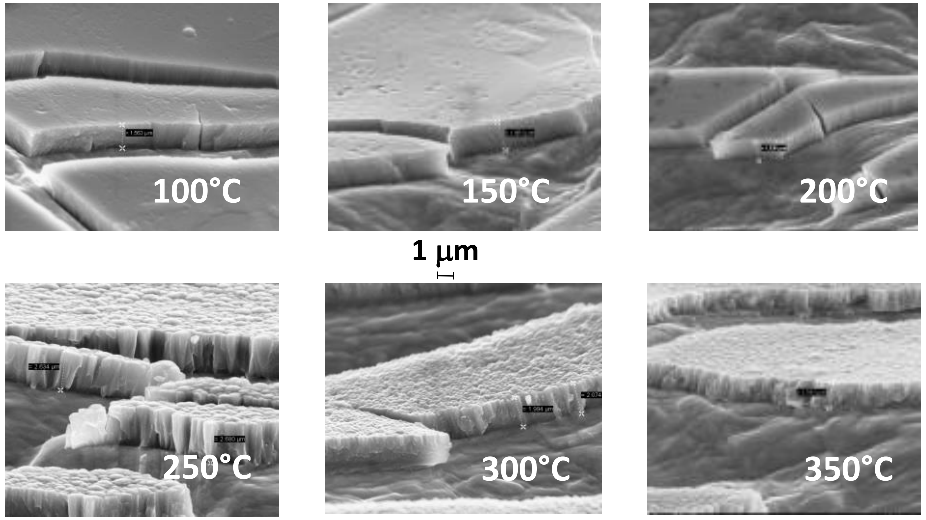
A. Prodromides et al., *Vacuum 60(2001)35*



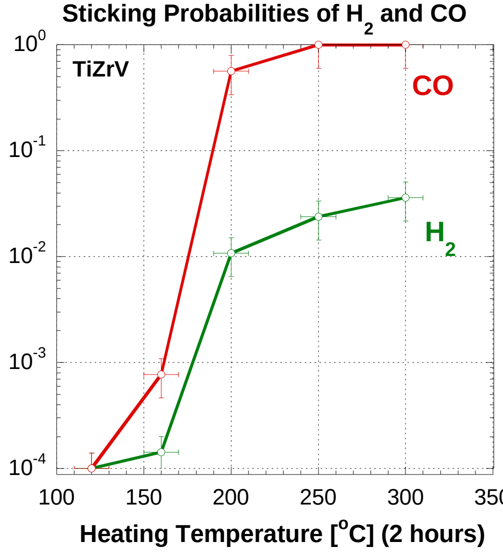


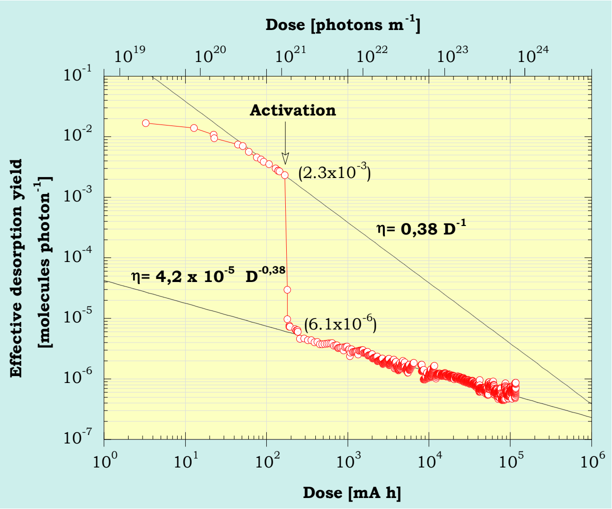
Microstructure of Ti-Zr-V films coated on Cu at different temperatures

C. Benvenuti et al., Vacuum 71(2003)307

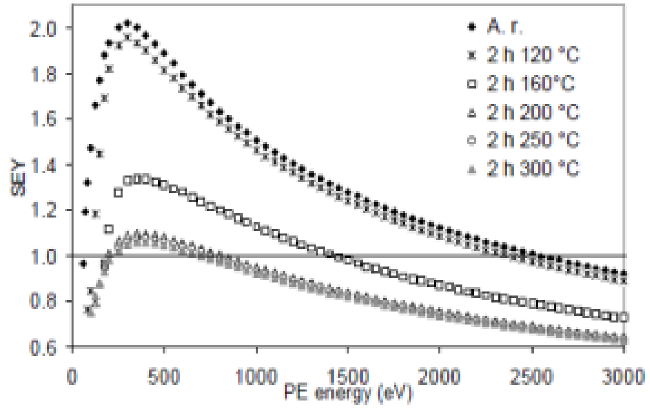


Courtesy of Nicola Black





P. Chiggiato and R. Kersevan, *Vacuum 60(2001)67*

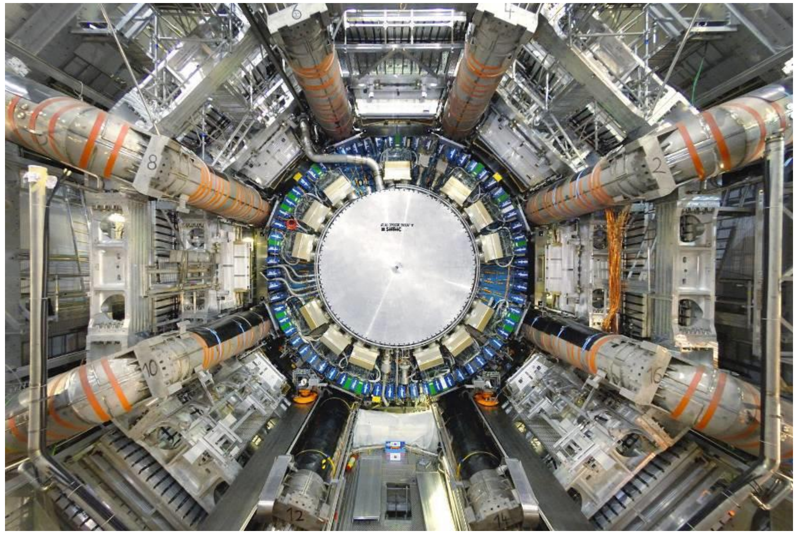


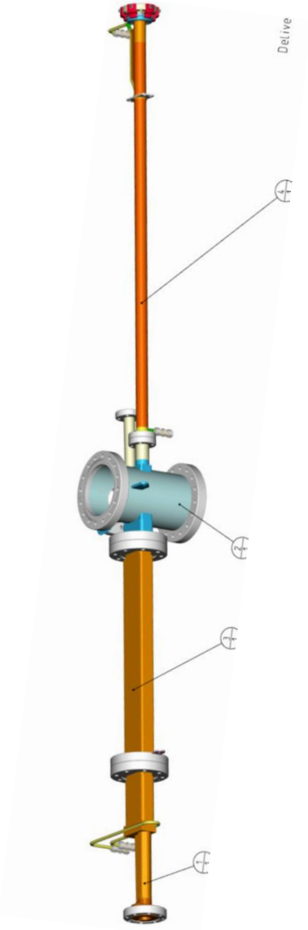
M. Taborelli et al.

Appl. Surf. Sci. 172 (2001) 95-102

Mitigation: Ti-Zr-V coating

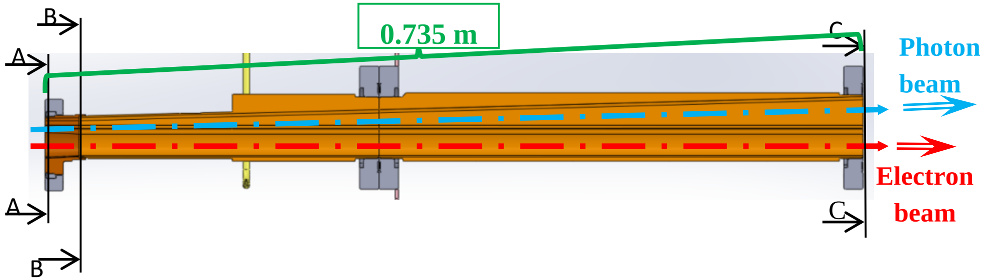
LHC Long Straight Sections

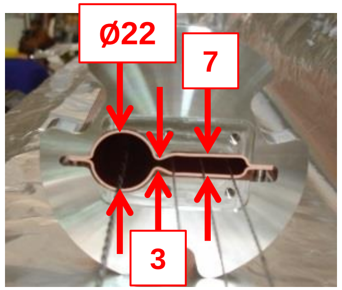


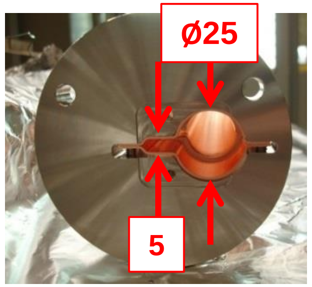


MAX IV at Lund (S)

Courtesy of Marek Grabki







Mitigation: a-C coating

- Ti-Zr-V film coating have δ_{max}≈1.1 after activation at temperature higher than 180°C (24h).
- But they cannot be applied to **unbaked vacuum** chambers like those of the LHC's injectors.
- **Carbon coatings** deposited by sputtering are a valid solution
  - *C. Yin Vallgren et al, PRST AB, 14, 071001 (2011).*
  - *P. Costa Pinto et al., Vacuum 98 (2013) 29*

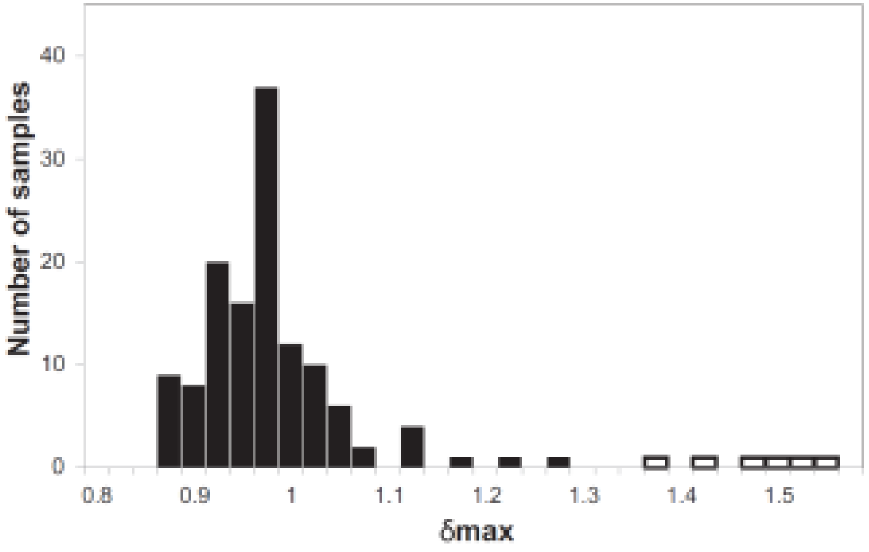
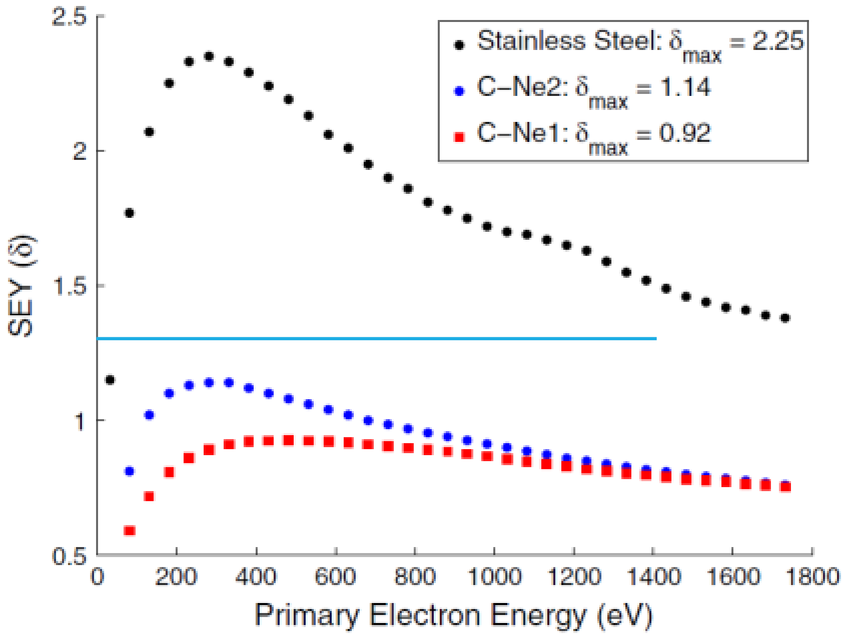
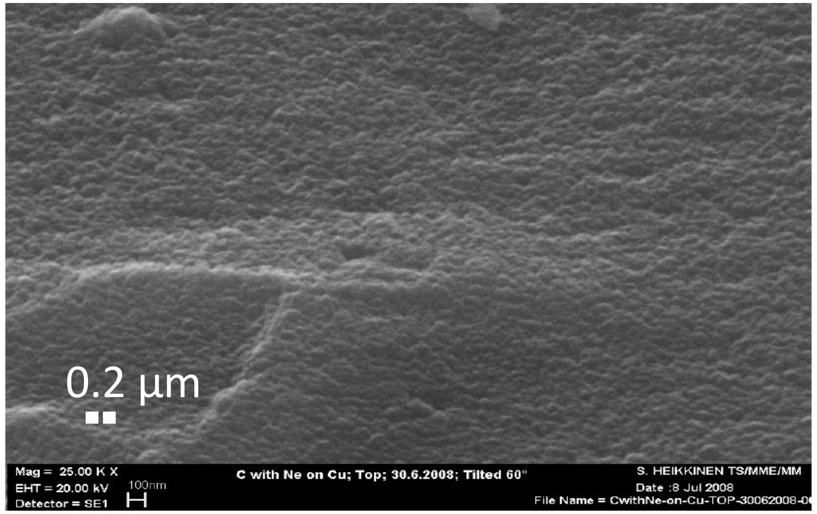
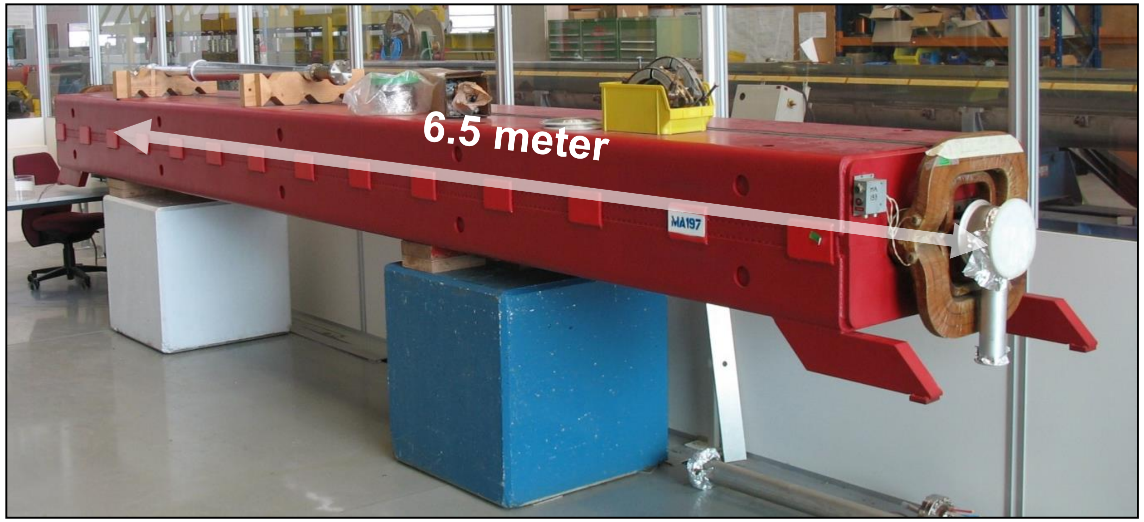


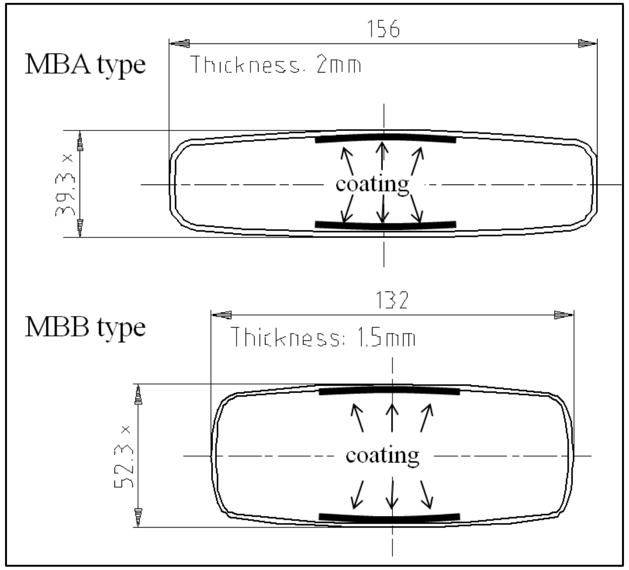
Fig. 2. Histogram of δ_{max}, with 119 samples deposited by MS (filled black columns) and 6 samples deposited by PECVD (empty columns).





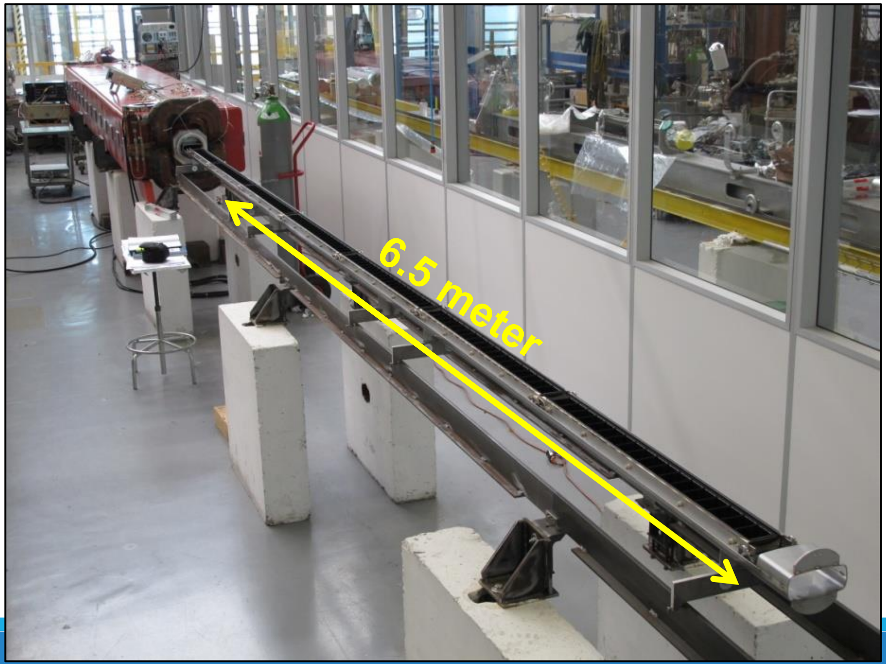
Mitigation: a-C coating

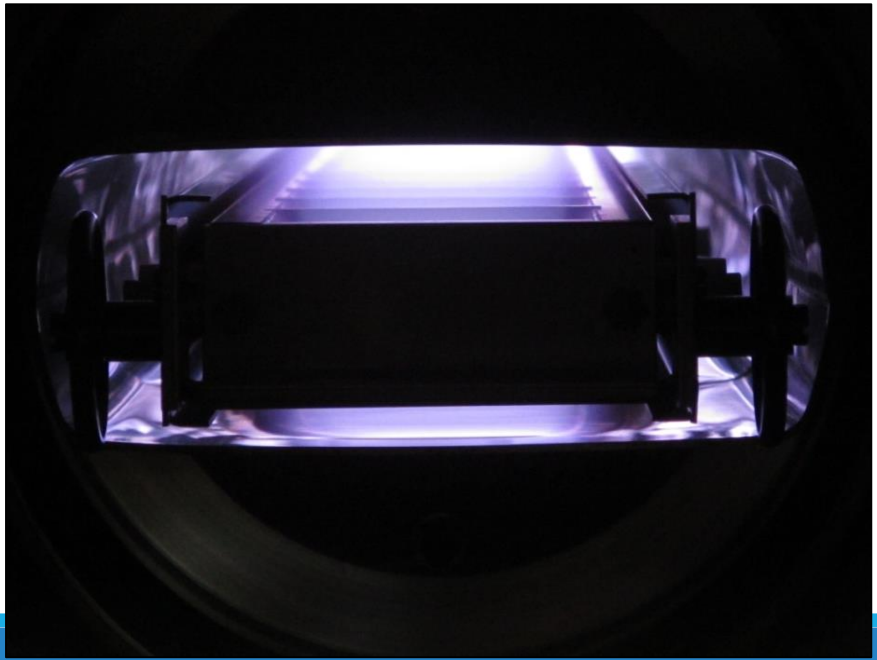




Coating by hollow cathode sputtering

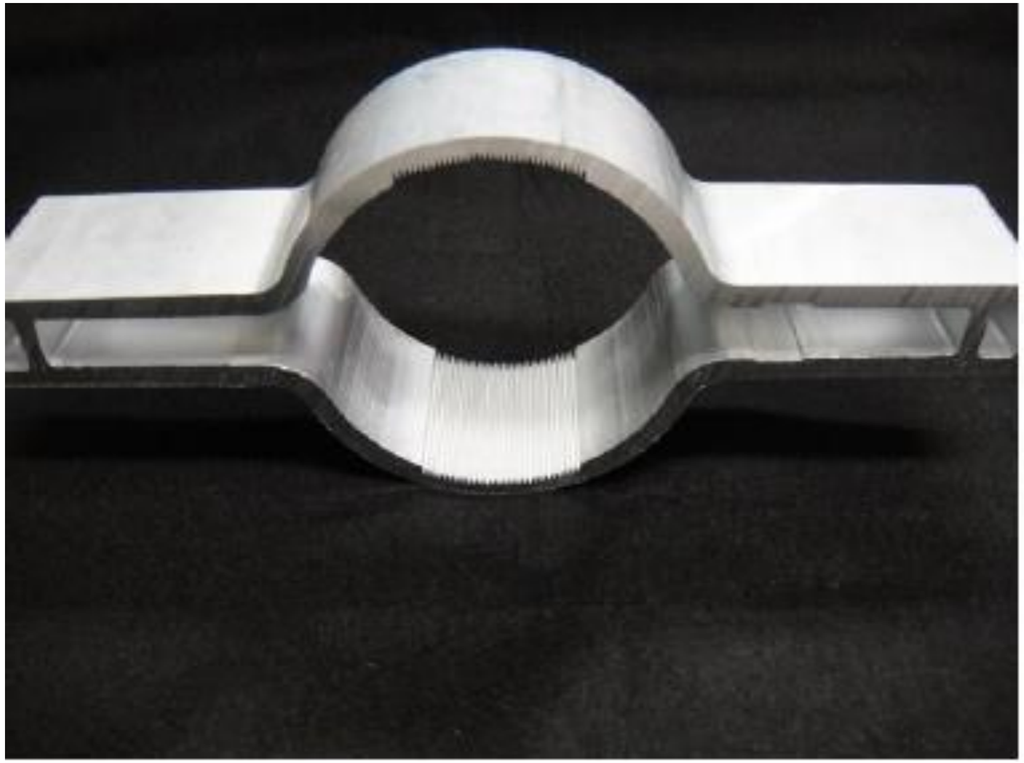
Courtesy of Pedro Costa Pinto

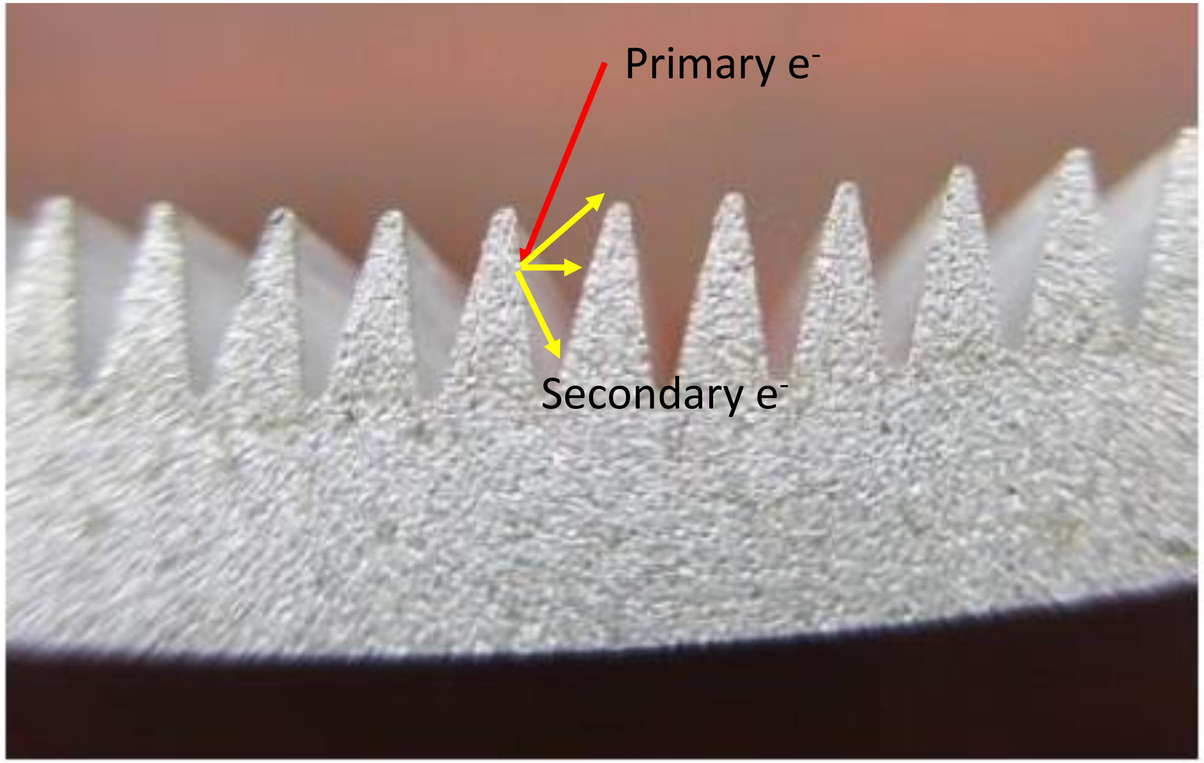




Mitigation: Machined Grooves

Courtesy of Y. Suetsugu, KEK





Mitigation: Machined Grooves

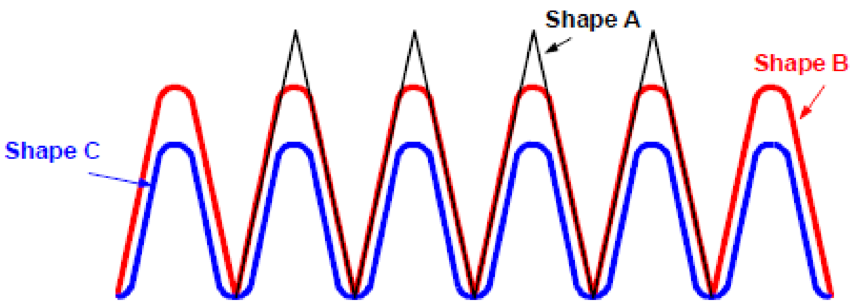
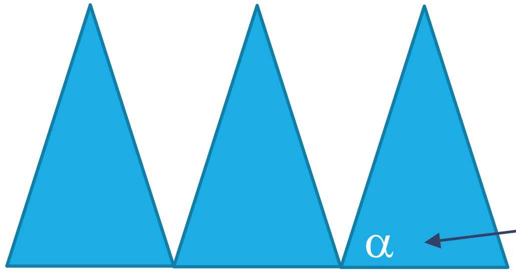


Figure 6: Triangular groove with different tips

The sharpest structure gives the lowest SEY.



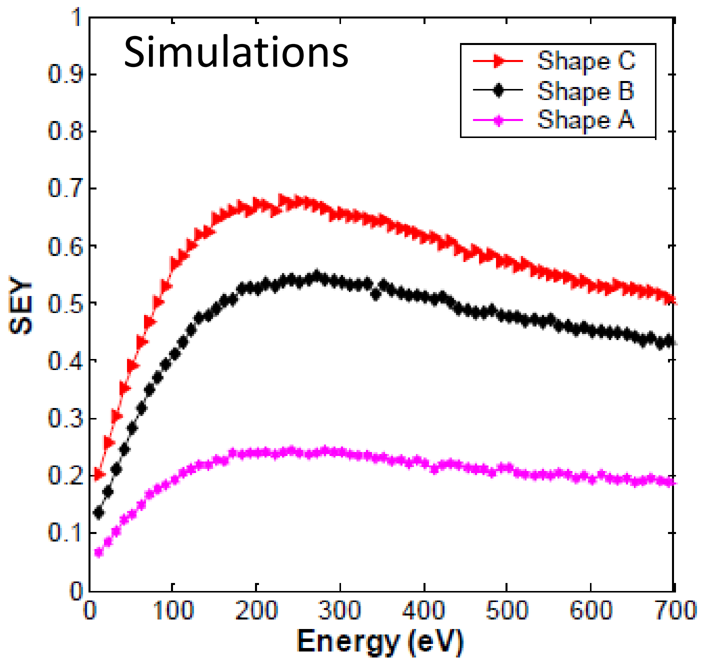


Figure 7: Effective SEYs of a triangular surface with different tips shown in Figure 6 (R_{tip}=0.2mm, W=2mm, α=80^0) in a magnetic field of 0.2 Tesla. The SEY parameters are δ_{max}=1.2 and E_{max}=330eV.

L. Wang et al., SLAC-PUB-12641 July 2007, presented at PAC 2007
M. Pivi, paf-spsu.web.ch

Mitigation: Laser Engineered Surface Structures

Physics Today, February 2013

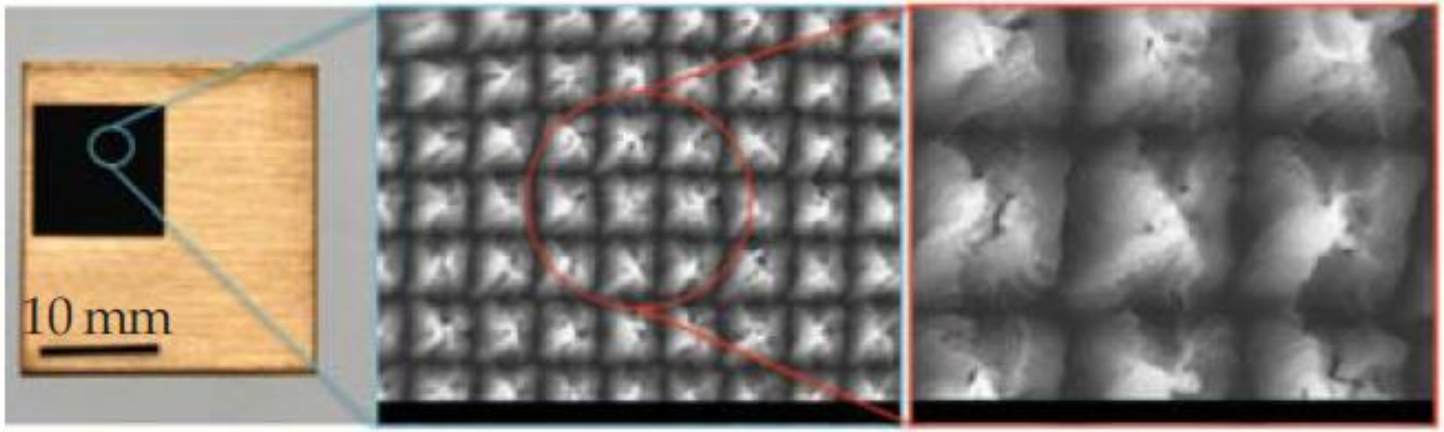
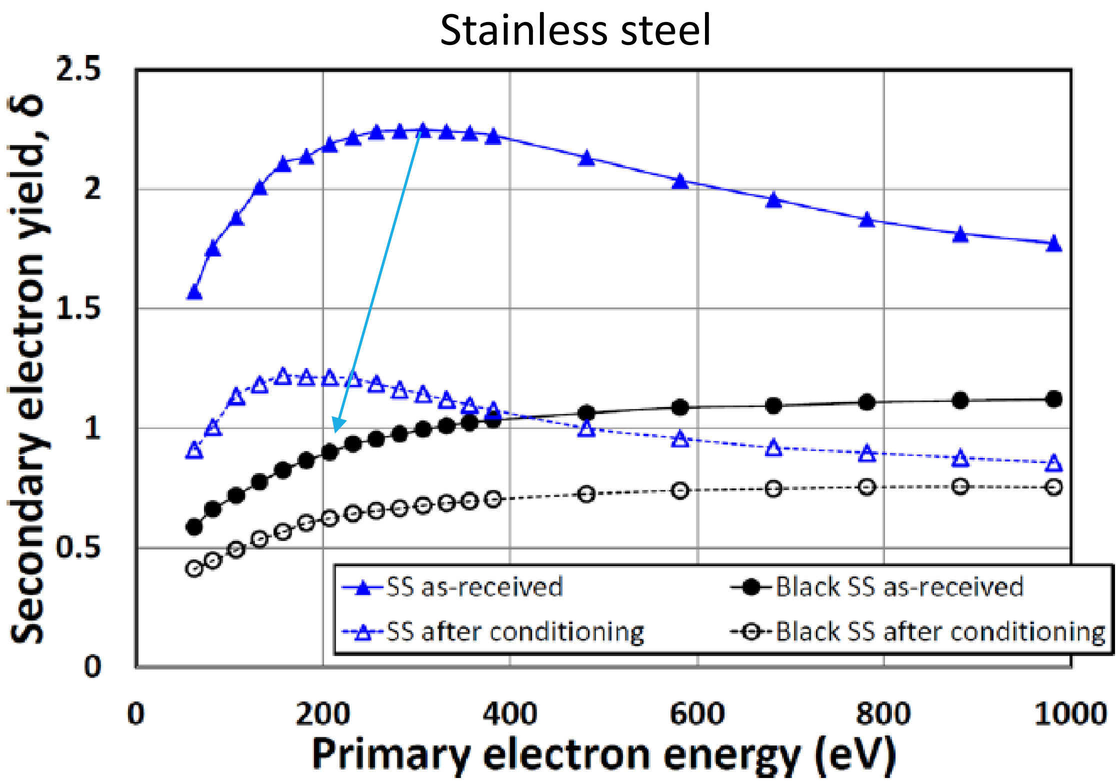


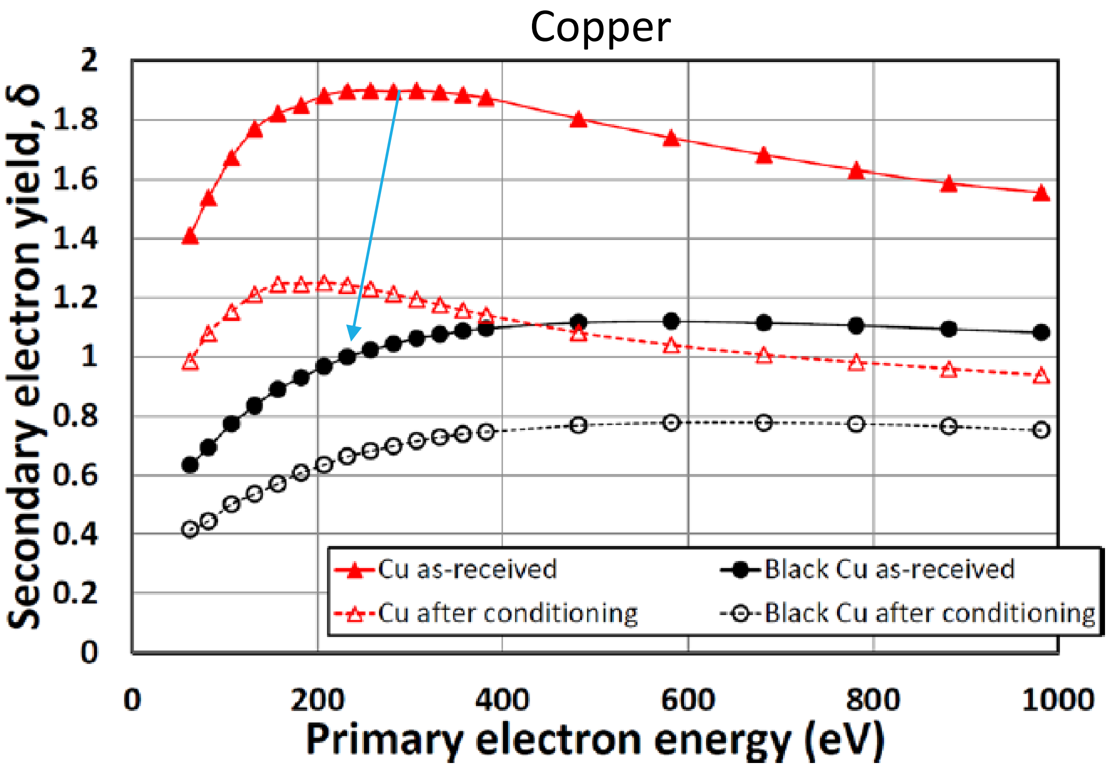
TABLE I. The δ_{max} of as-received and conditioned samples.

	Initial		After conditioning to Q_{max}		
Sample	δ_{max}	E_{max} (eV)	δ_{max} (Q_{max})	E_{max} (eV)	Q_{max} (C·mm^{-2})
Black Cu	1.12	600	0.78	600	3.5×10^{-3}
Black SS	1.12	900	0.76	900	1.7×10^{-2}
Black Al	1.45	900	0.76	600	2.0×10^{-2}
Cu	1.90	300	1.25	200	1.0×10^{-2}
SS	2.25	300	1.22	200	1.7×10^{-2}
Al	2.55	300	1.34	200	1.5×10^{-2}

R. Valizadeh, Appl. Phys. Lett. 105, 231605 (2014)

Mitigation: Laser Engineered Surface Structures





R. Valizadeh, Appl. Phys. Lett. 105, 231605 (2014)

Heating issues

Bernhard Holzer, in one of the previous CAS:

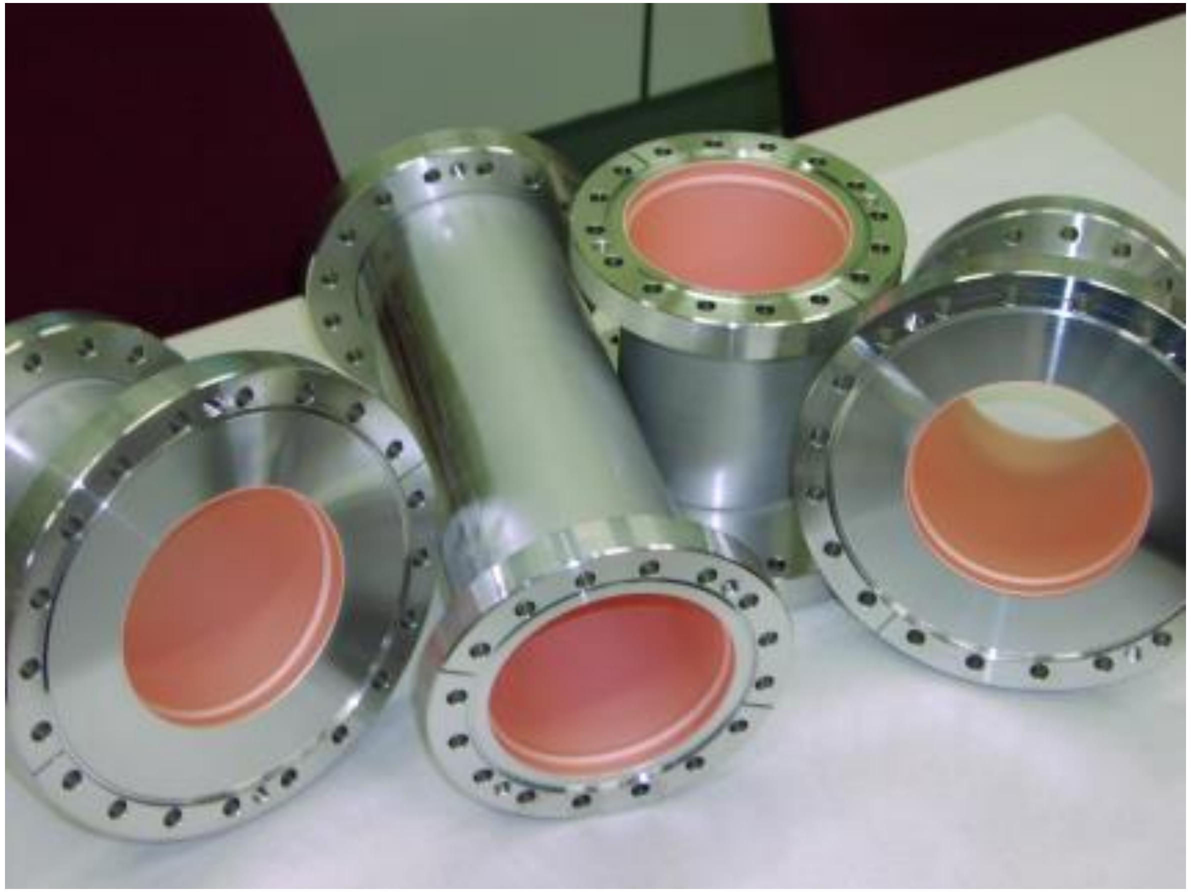
''There are no collective instabilities and there is no heating,
if the following conditions are fulfilled:

the beam is ultra relativistic
the vacuum chamber is smooth
the vacuum chamber material is perfectly conducting.

Unfortunately these conditions are not realistic.''

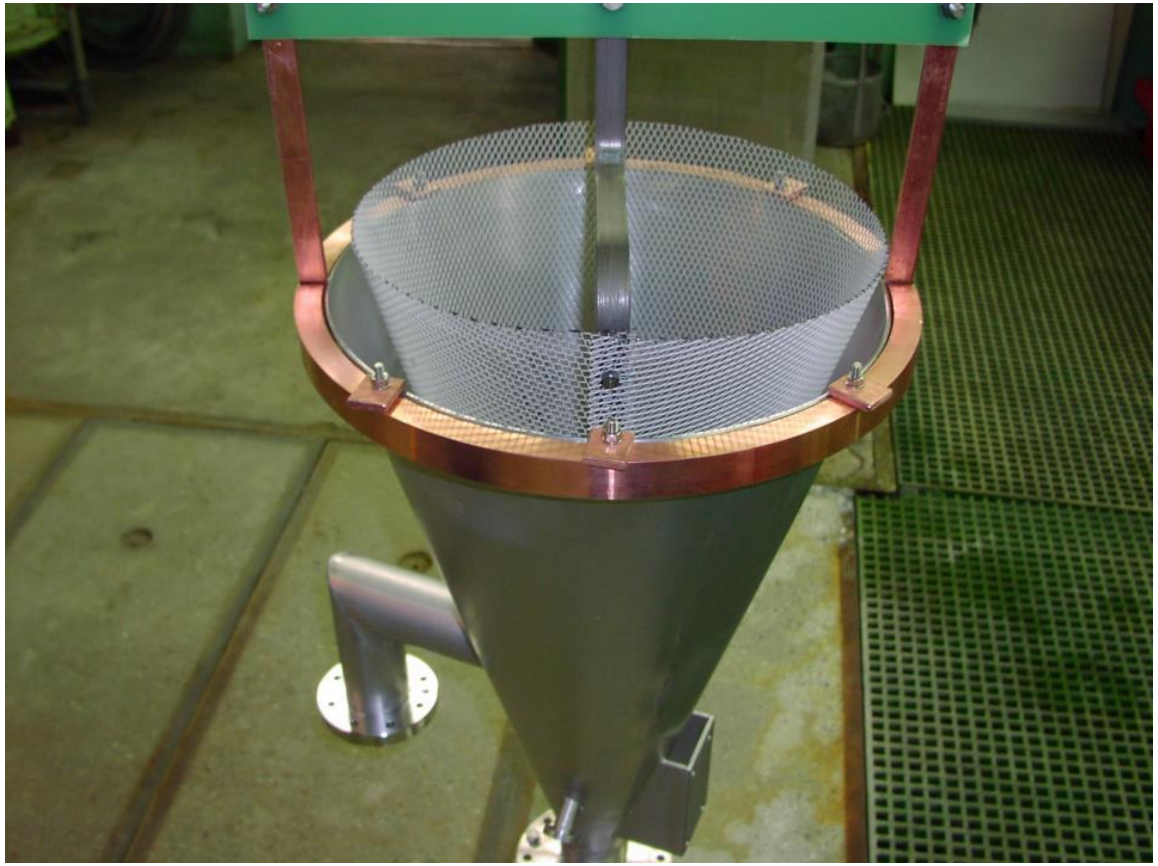
B. Holzer, HOMS and Heating, CAS Superconductivity for Accelerators, 2013
CERN Yellow Report CERN-2014-005, pp.97-110

Heating issues: reduction of beam pipe electrical resistance



When the beam pipe has a small diameter and it is not made of copper, copper electroplating is applied.

Heating issues: reduction of beam pipe electrical resistance



Cu atoms are provided by a Cu sulphate acid bath. The Cu layer on stainless steel needs an adherence layer of Ni and a final neutralisation and passivation.

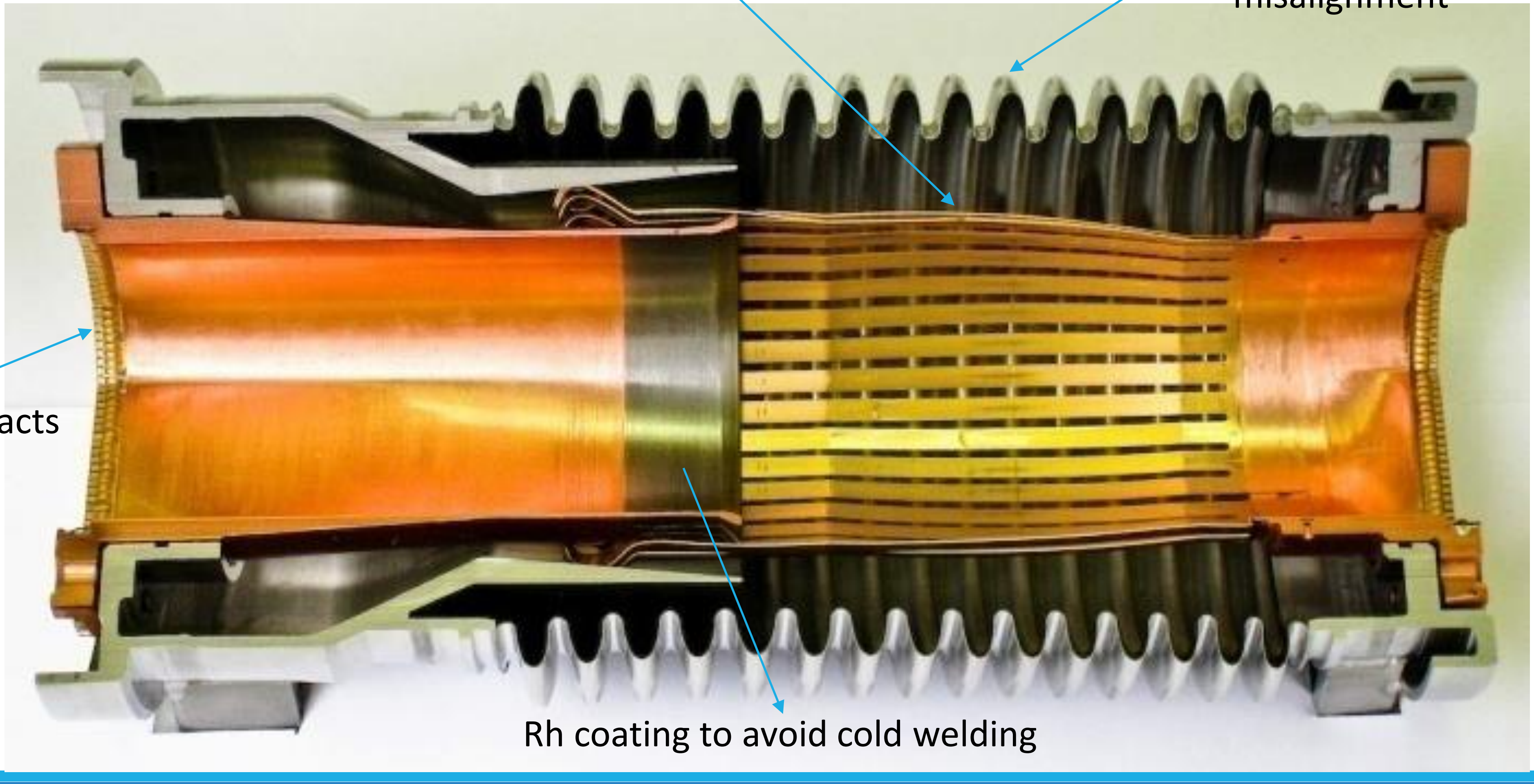
For the LHC, electroplating was applied to **vacuum chambers as long as 5 m** (**≈5 cm diameter**).

Heating issues: smoother beam pipe transitions

Cu-Be fingers ensure short-path electrical contacts and ‘geometrical uniformity’ between two LHC beam screens

Au coated Cu-Be fingers for electrical and geometrical continuity

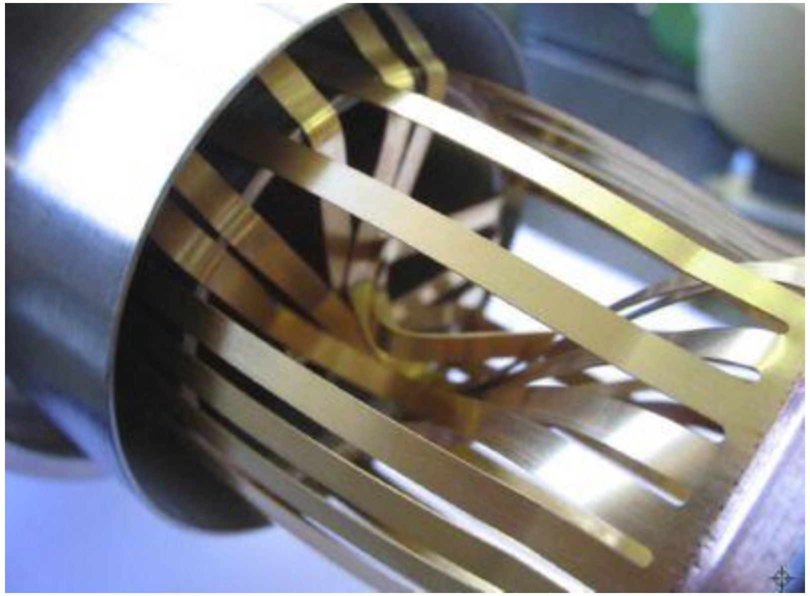
Bellow for compensation of thermal expansion and small misalignment

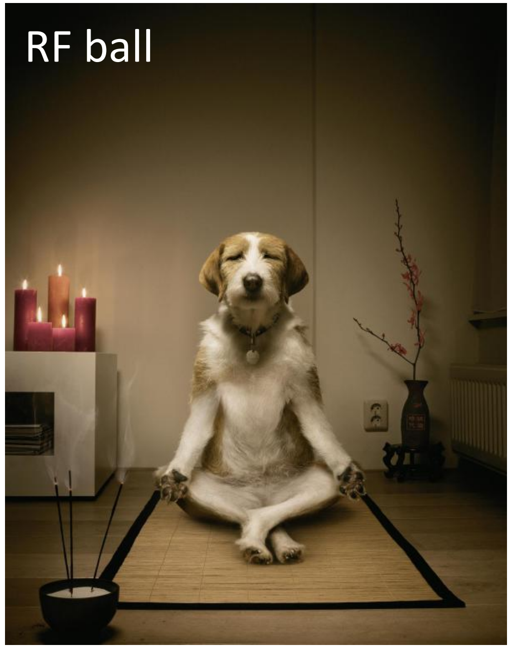


Electrical contacts

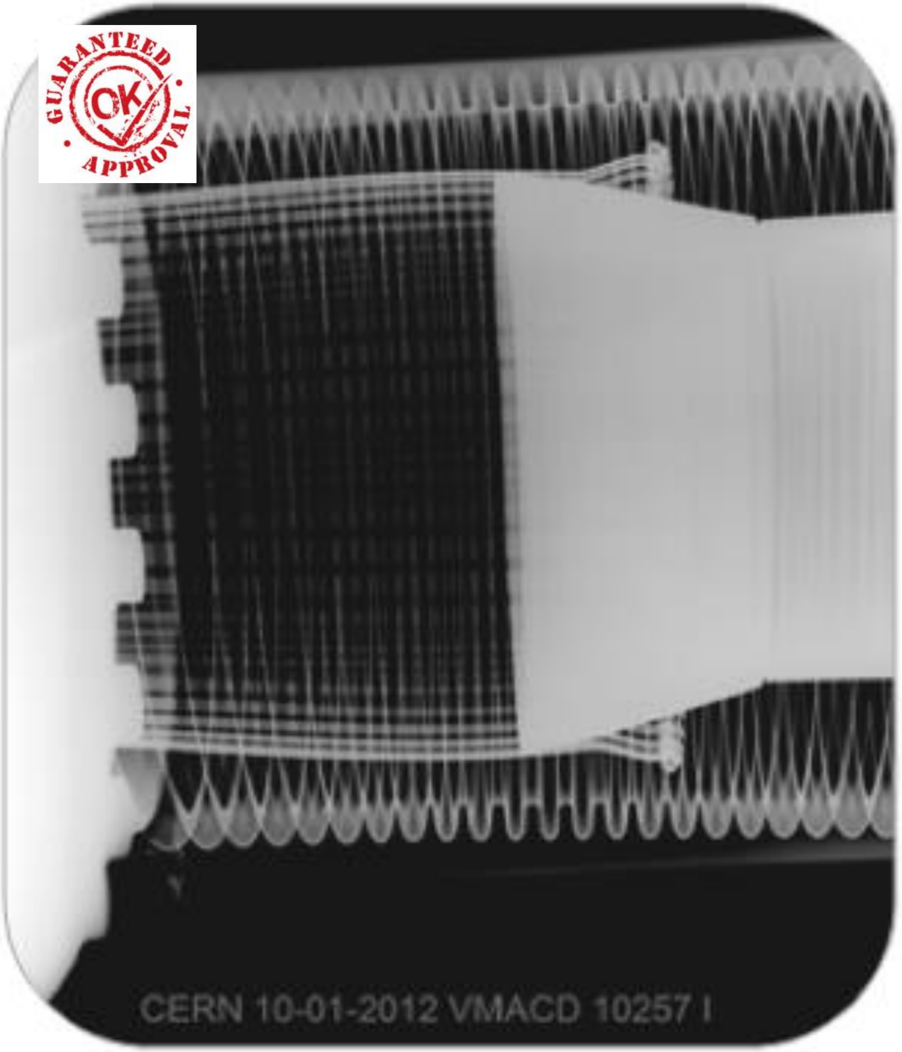
Rh coating to avoid cold welding

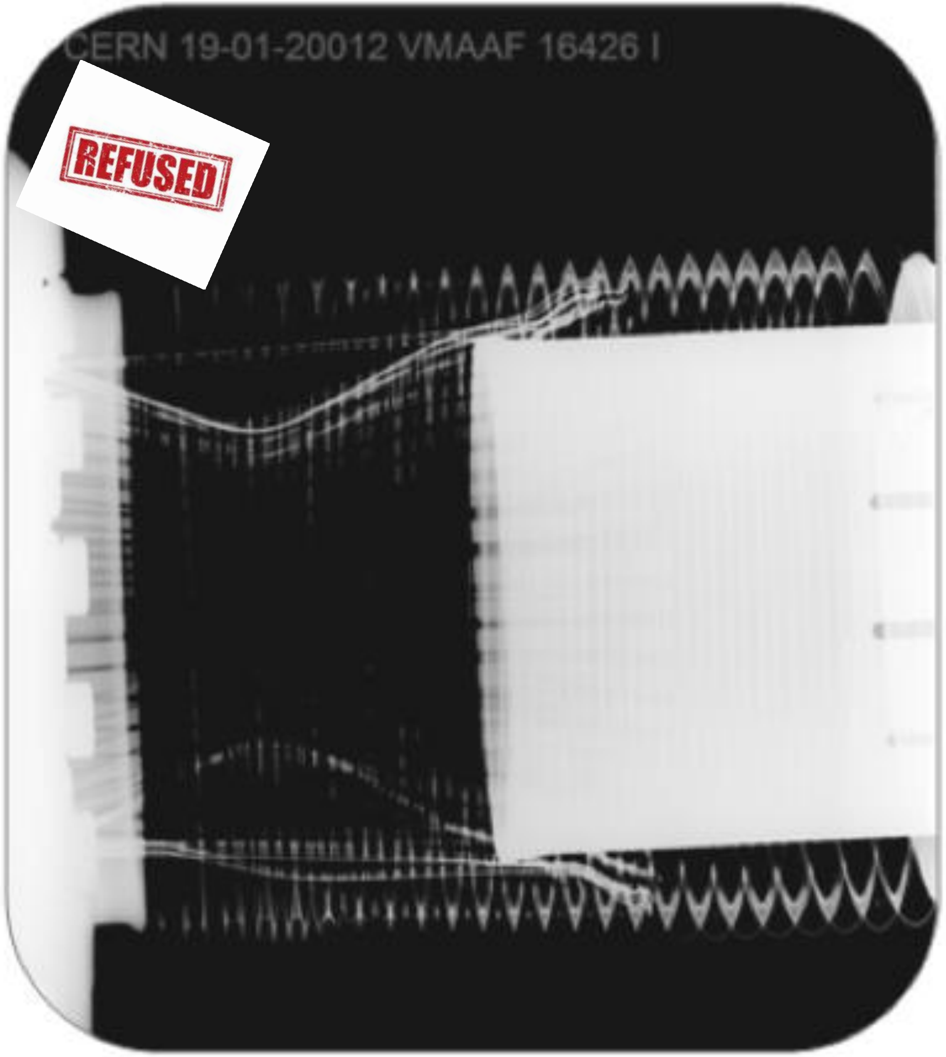
Heating issues: smoother beam pipe tran.





Heating issues: smoother beam pipe transitions

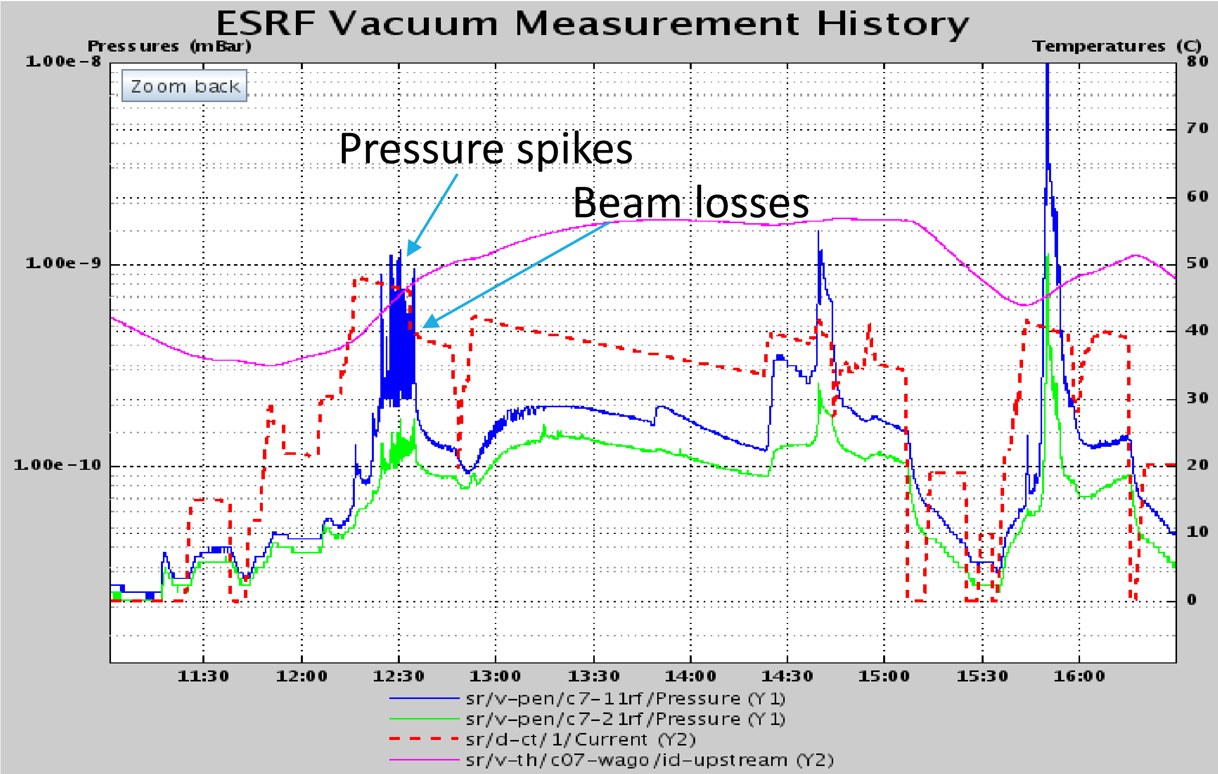




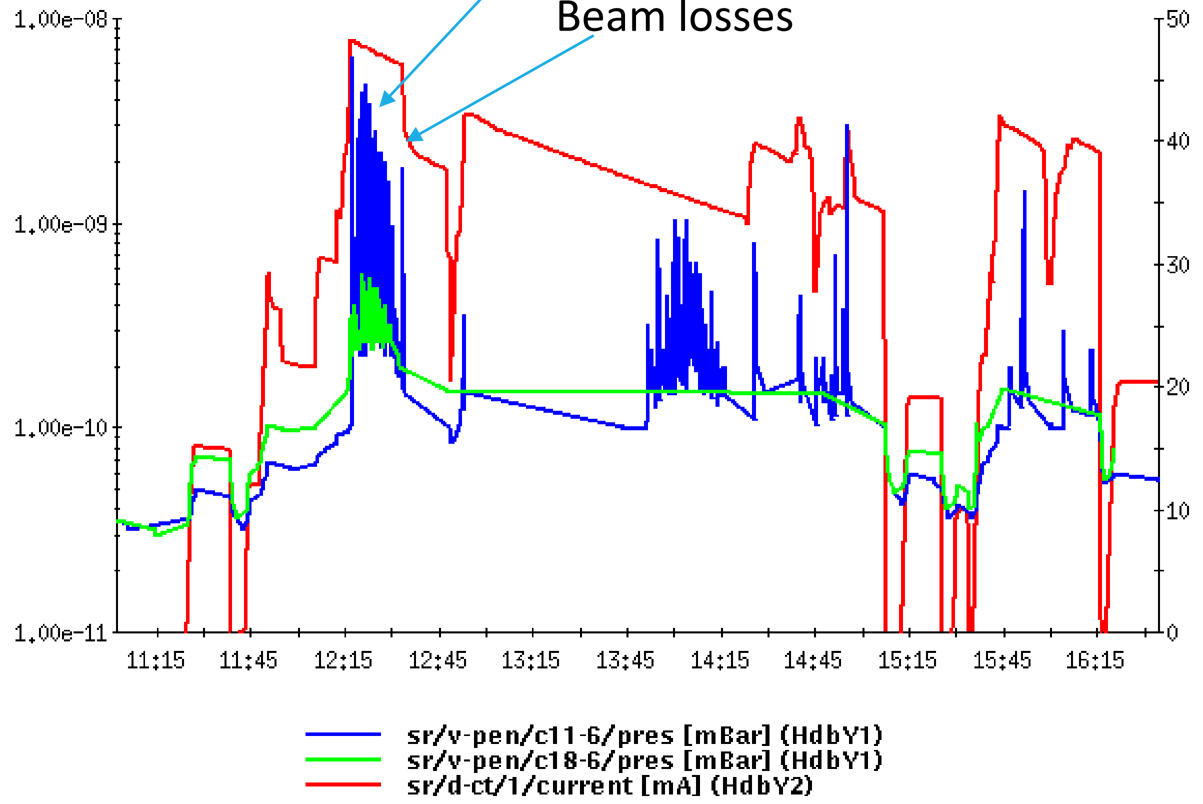
During the LS1, 1800 X-ray tomography were carried out
92 non-conformities were recorded, mostly on two families of RF fingers: circular and elliptical (VMTSA)

Heating issues: smoother beam pipe transitions

ESRF issues with RF fingers



SR cavity3 : **RF fingers** on the upstream bellow



RF fingers problems on CV11 in (4x 10mA)

Pressure spikes affecting the beam lifetime, increasing the bremsstrahlung dose to beamlines (important safety aspect), potentially preventing operation (fingers can melt and go in the way of the beam).
New/improved design had to be studied. Long procurement time.

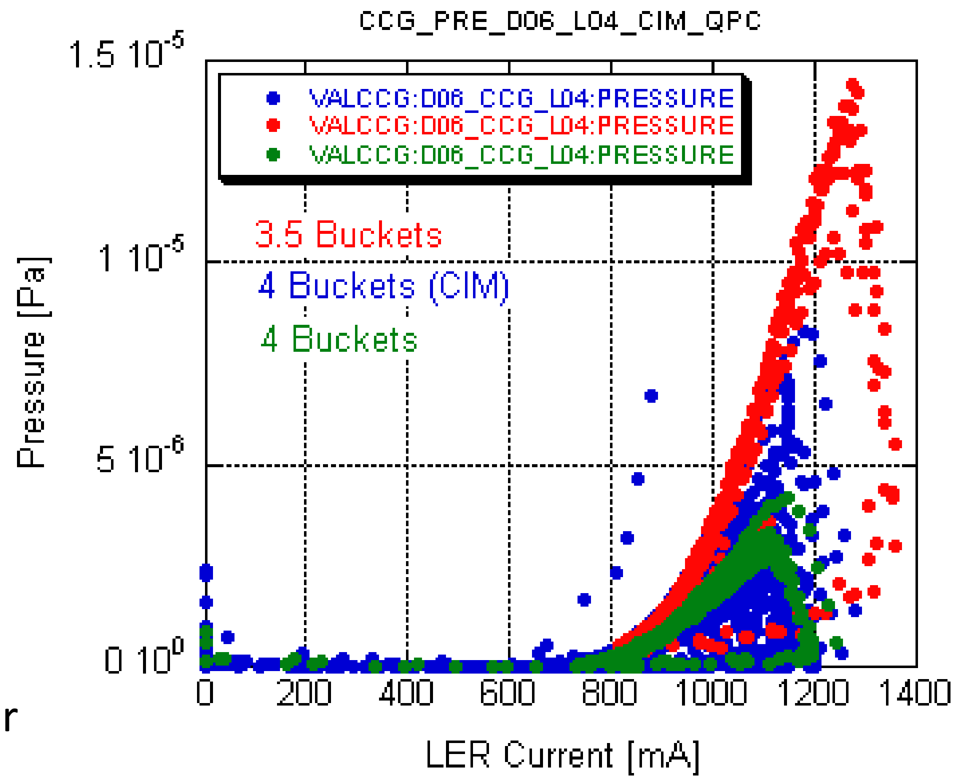
Courtesy of Roberto Kersevan

Heating issues: smoother beam pipe transitions

HOM in LER (KEK)

KEK: Pressure rise was observed for beam currents higher than ~800 mA (LER).

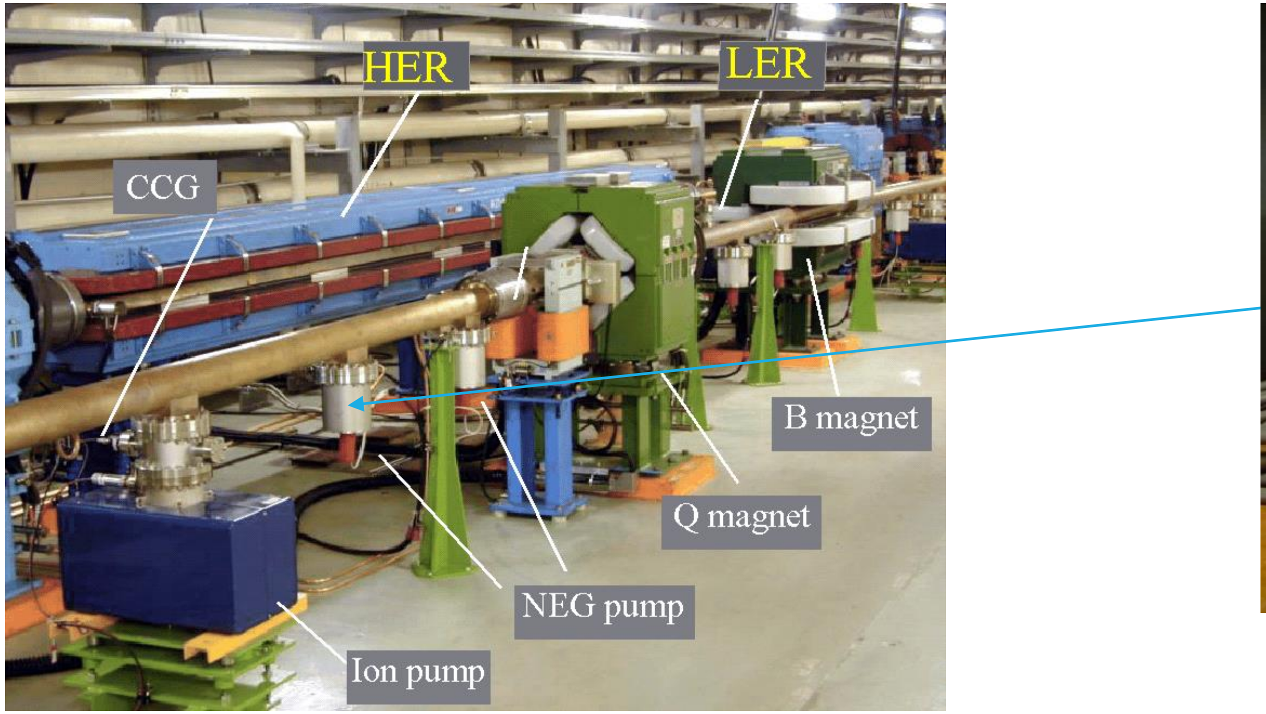
- Pressure rises rapidly against the current.
- But it has a hysteresis behavior (heating)
- Insensitive to bunch fill pattern
- Vacuum scrubbing proceeds slowly

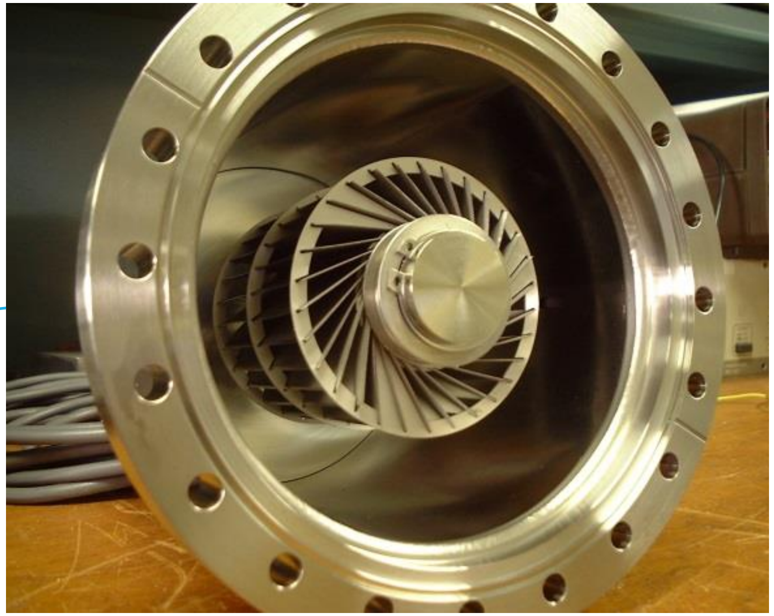


Characteristics

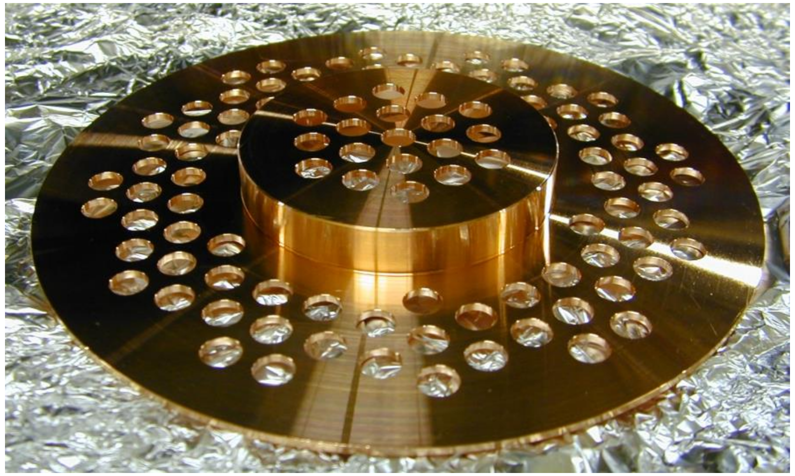
- Only near special vacuum components, i.e. movable masks (collimators) → big HOM sources (several kW)
- Temperature of NEG chamber near mask is higher than other ones (estimated temperature > 150 ° C)
- Pressure distribution is almost same as the temperature's
- Desorbed gas is H_2

Courtesy of Y. Suetsugu, KEKB Vacuum Group, 2003





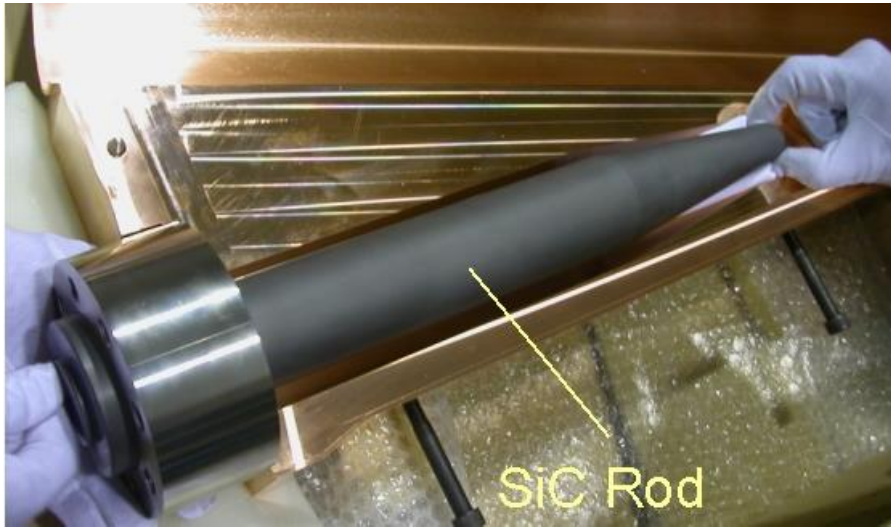
RF masks worked but not perfectly

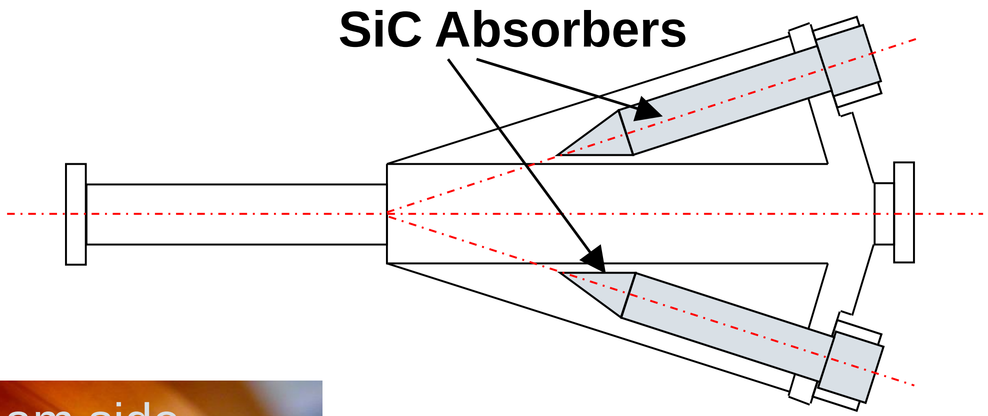


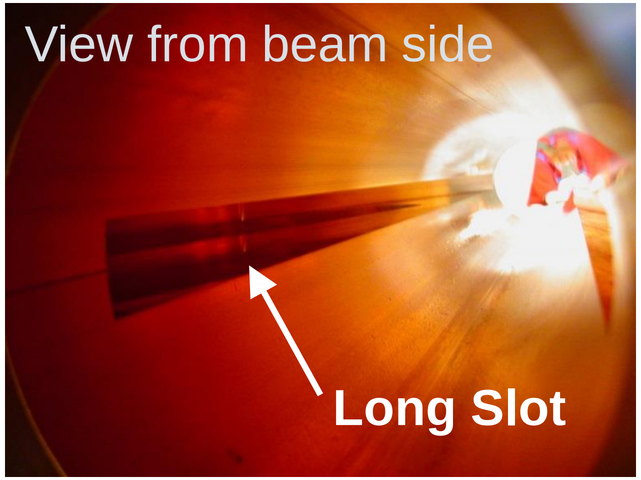
Courtesy of Y. Suetsugu, KEKB Vacuum Group, 2003

Heating issues: smoother beam pipe transitions

- HOM dampers were installed near movable masks
- The HOM dampers damp preferentially the TE11 mode







Attention! Good HOM dampers could be very bad for vacuum due to high thermal outgassing; for example ferrites…

Courtesy of Y. Suetsugu, KEKB Vacuum Group, 2003

Conclusions

- Safety of the personnel, in particular with respect to radioactivity dose, must be your first thought when designing high-intensity accelerators.
- The gas load is a challenge: high-intensity beams induce gas desorption by electrons, photons and ions.
- Beam-induced particle bombardment (beam conditioning) is efficient in reducing desorption, SEY and photoelectron yields.
- We have in our hands several mitigation techniques for both gas load and electron multipacting; they should be considered from the first phase of design.
- Surface smoothness and continuity can be improved. There is margin for a better design, optimisation and additional development.

END