Some Vacuum Related Diagnostics of High Energy Particles Accelerators

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CERN TE-VSC, Geneva

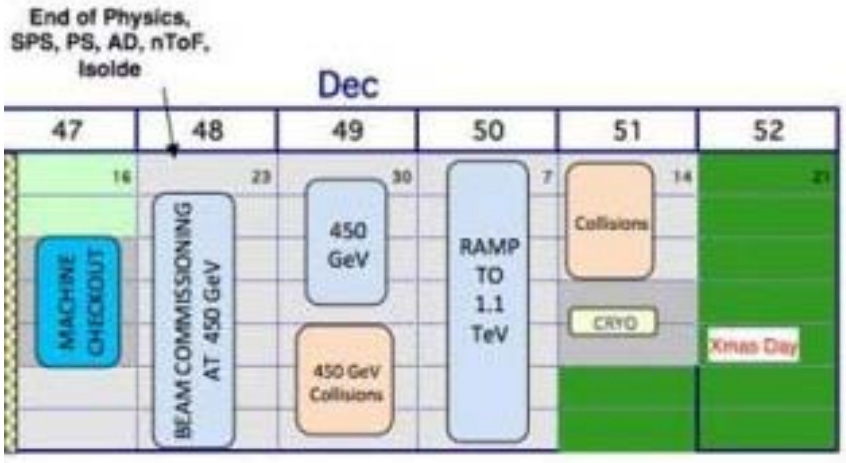
1. Vacuum gauges
2. Instruments in machines
3. Future instruments

Advertisement

- This talk is a general overview of some devices used in high energy particle accelerators
- I am not a specialist in the field of energy spectrum of particles

Preamble

- The Large Hadron Collider started last Friday 20th of November
- Both beams are circulating
- Collision at 450 GeV foreseen early next week
- Collisions at 1.2 TeV before the end of the year

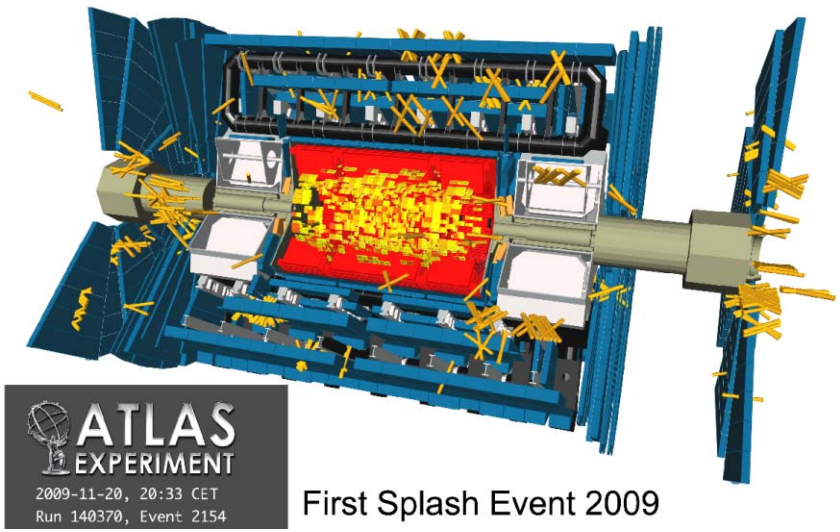


"These developments come just three days after the LHC restart, demonstrating the excellent performance of the beam control system. Since the start-up, the operators have been circulating beams around the ring alternately in one direction and then the other at the injection energy of 450 GeV. The beam lifetime has gradually been increased to 10 hours, and today beams have been circulating simultaneously in both directions, still at the injection energy.
Next on the schedule is an intense commissioning phase aimed at increasing the beam intensity and accelerating the beams. All being well, by Christmas, the LHC should reach 1.2 TeV per beam, and have provided good quantities of collision data for the experiments' calibrations."

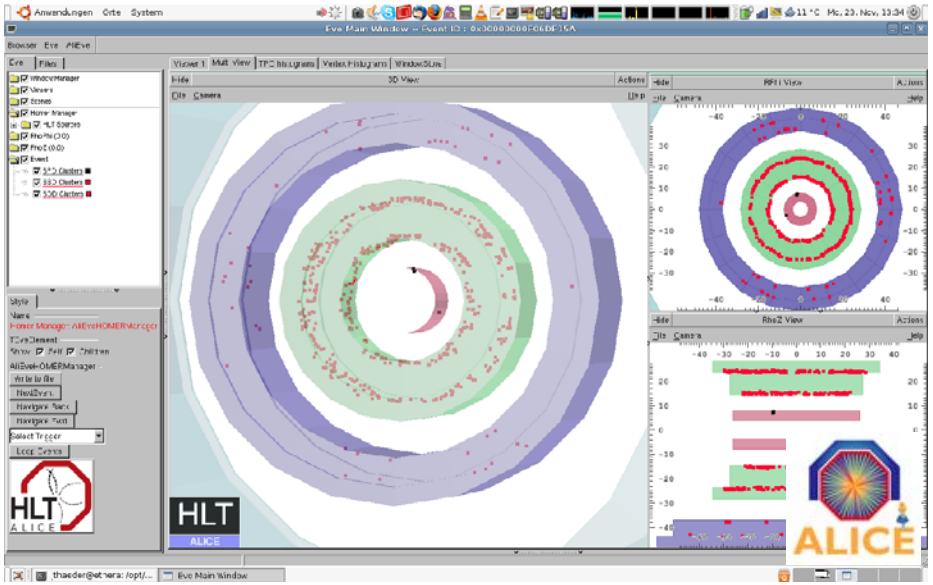
R. Heuer, Monday 23rd of November

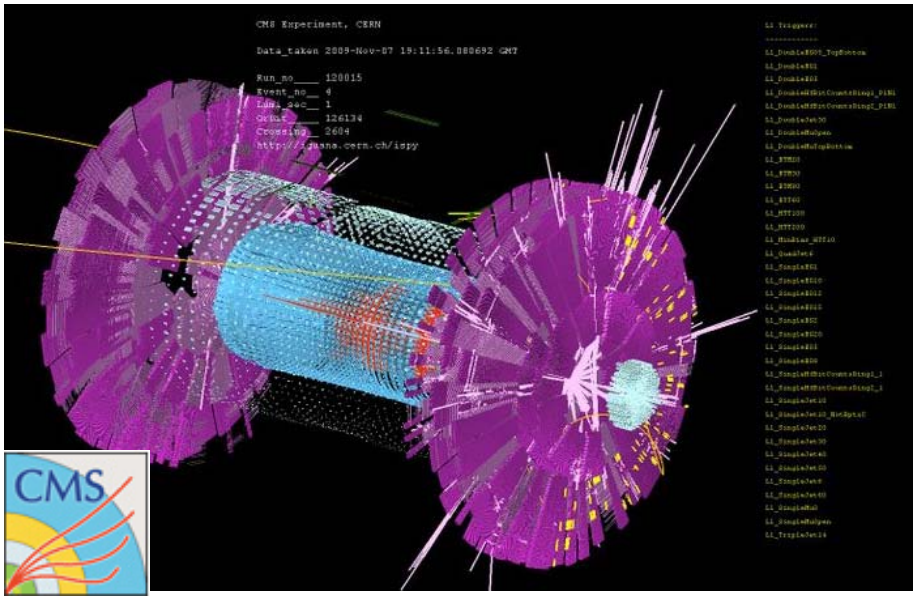
Press release : http://press.web.cern.ch/press/PressReleases/Releases2009/PR17.09E.html

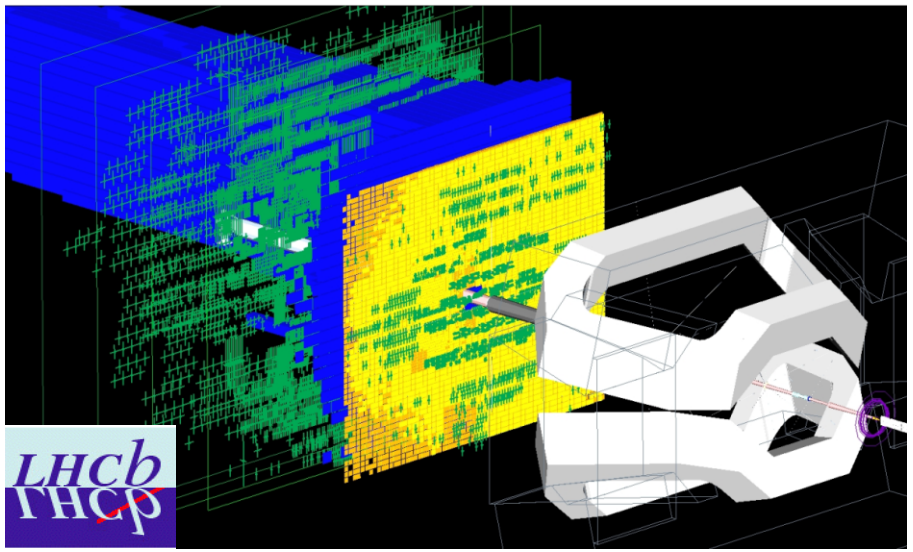
On 20th of November … splash events from collimators



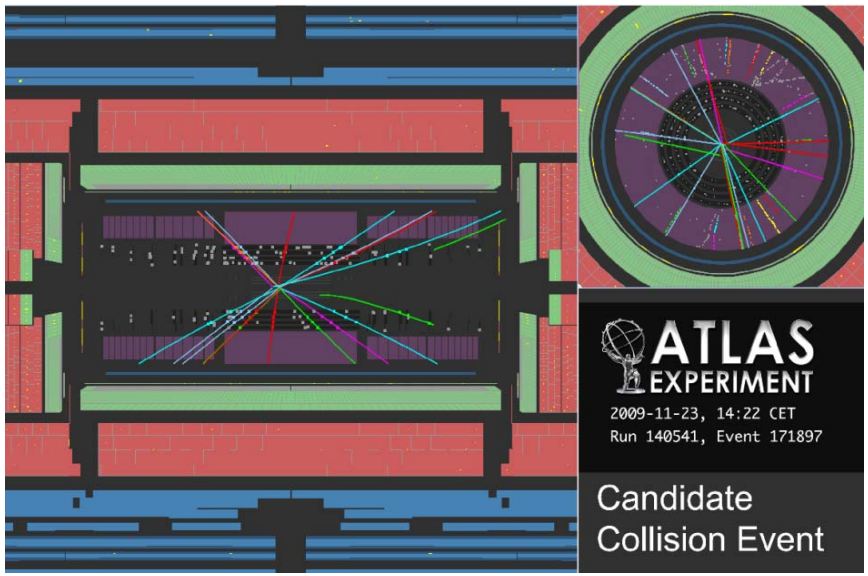
First Splash Event 2009

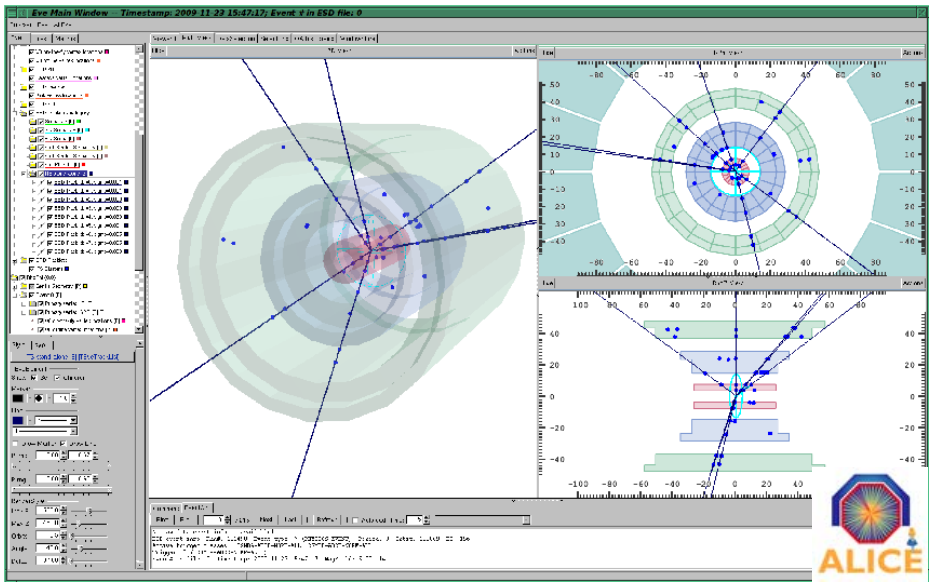


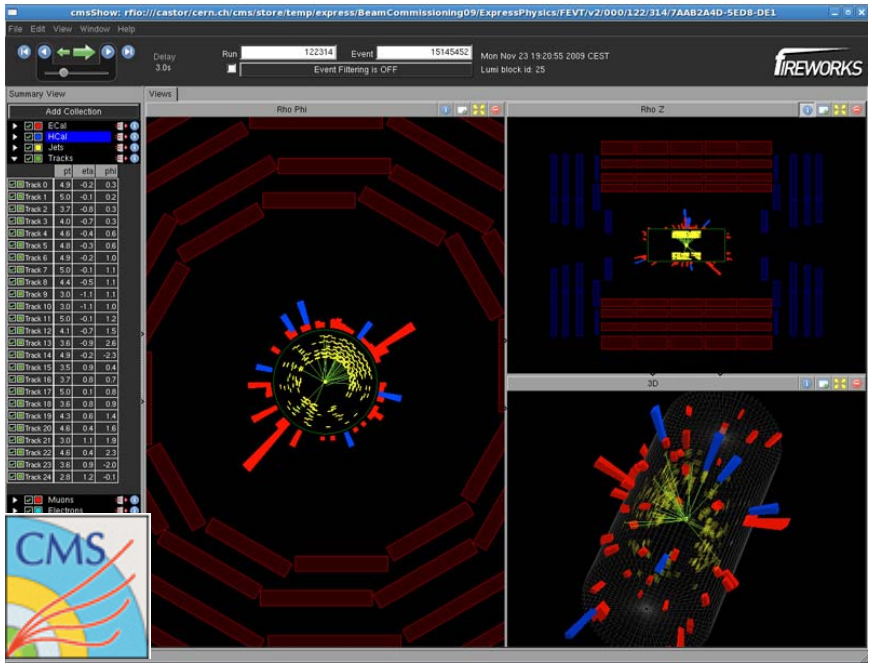


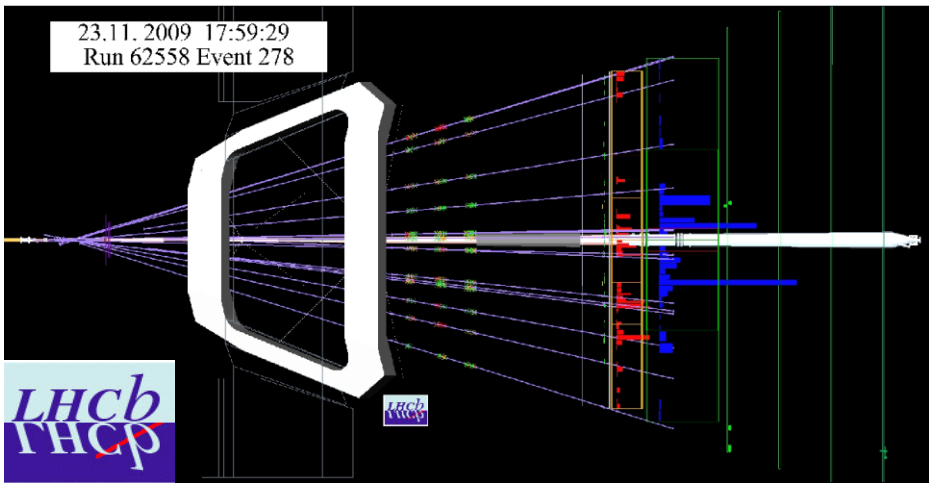


On 23rd of November … first single bunch collisions at 450 GeV









1. Vacuum gauges

Ultra High Vacuum Gauges

- With the appearance of UHV due to progress in cleaning, baking technologies and pumping mechanism, the measurement of very low pressure became important.

- In the 50's the X-ray limit of the Bayard-Alpert gauge was reduced allowing measurements to 10^{-12} mbar

- Main limitations of pressure measurement :

  - Ejection of photoelectrons from the collector caused by X-rays arising from electron bombardment of the grid

  - Production at the grid of ions from the adsorbed gas layer by electron stimulated desorption

P. Redhead. JVSTA A21(5) Sep/Oct 2003, S1

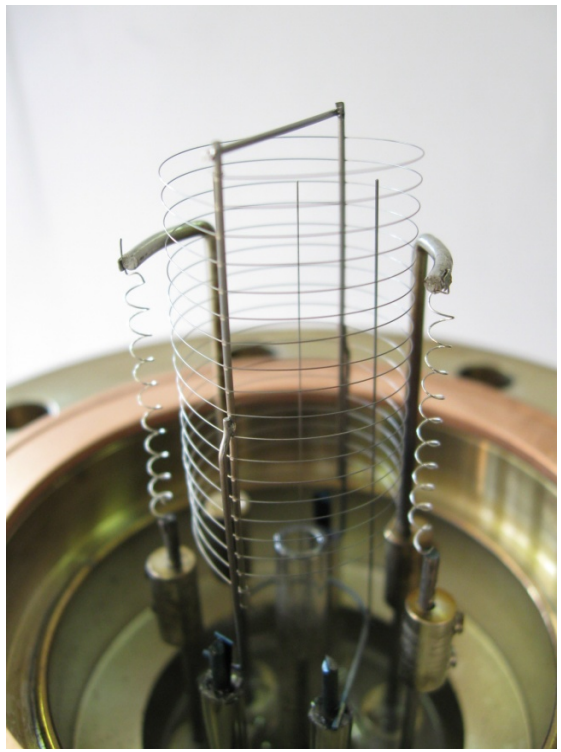
Bayard-Alpert Gauge

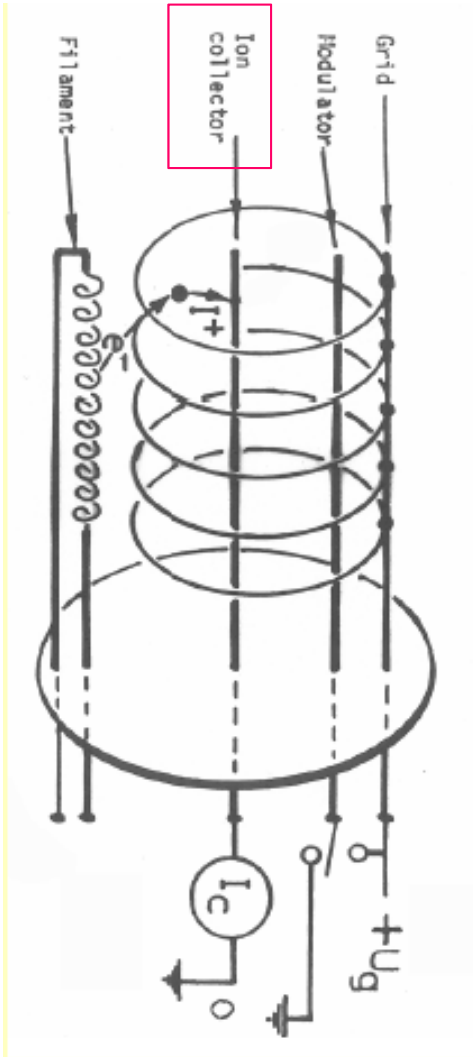
- Bayard-Alpert gauges are used for vacuum measurement purposes in the range 10^{-5} -10^{-12} mbar.

- It is a hot filament ionisation gauge. Electrons emitted by the filament perform oscillations inside the grid and ionise the molecules of the residual gas. Ions are then collected by an electrode.

$$I^+ = I^- \sigma n L$$

Where :
I^+ is the ion current
I^- is the filament current
σ is the ionisation cross section
n the gas density
L the electron path length





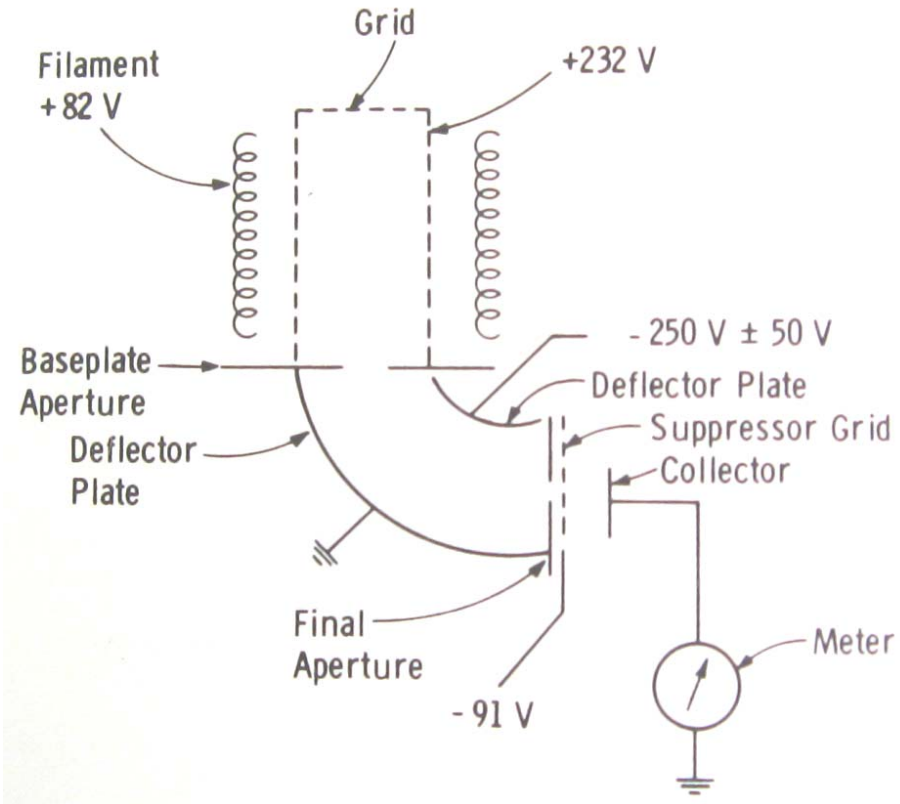
- The gauge needs to be calibrated

- X-ray limit of a few 10^{-12} mbar

Helmer vacuum gauge

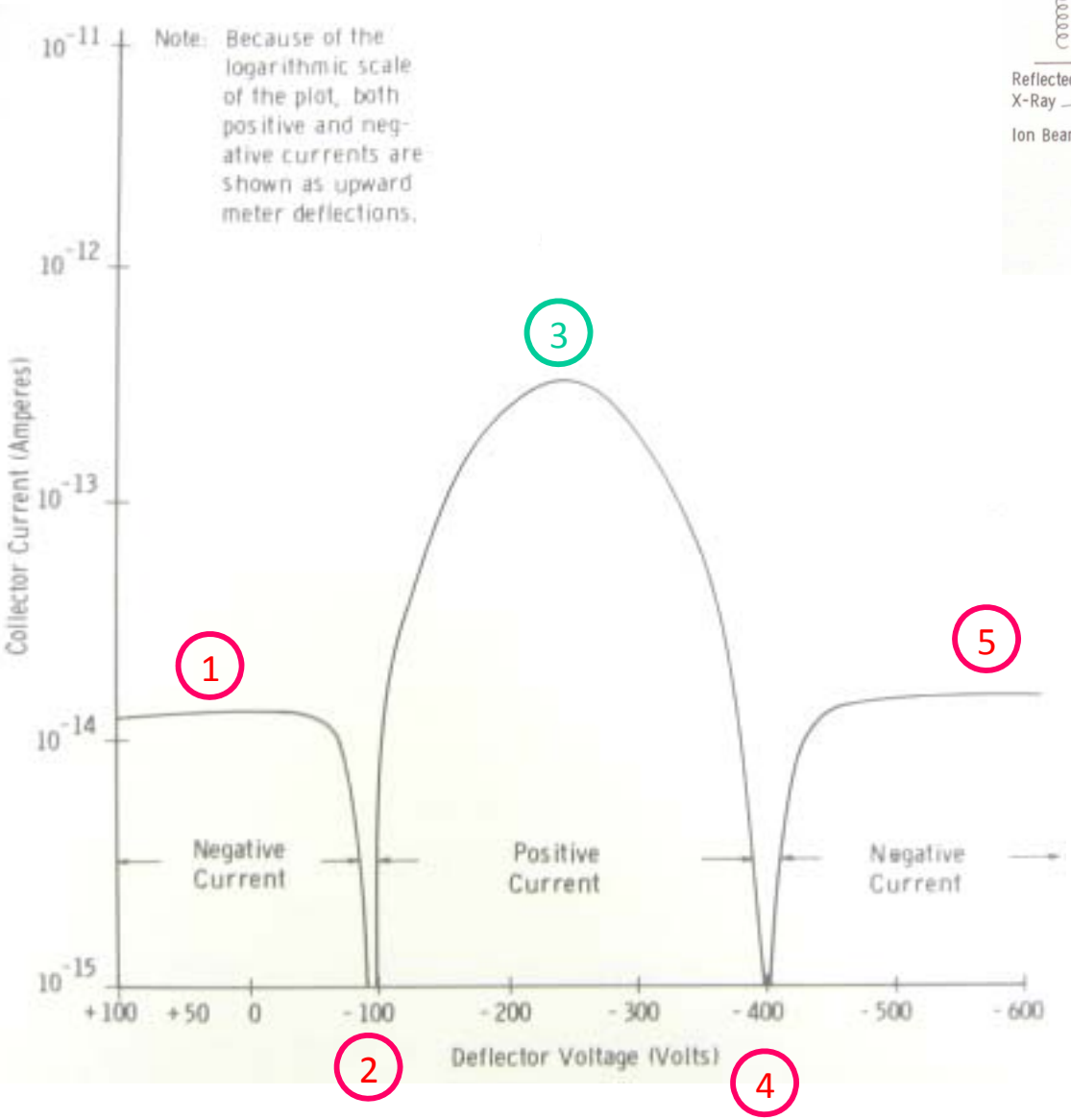
- A 90° cylindrical electrostatic energy filter slightly separate the ESD from gas phase ions on the basis of their initial kinetic energy and reduce the X-ray limit by shielding the ion collector from direct X-ray flux.

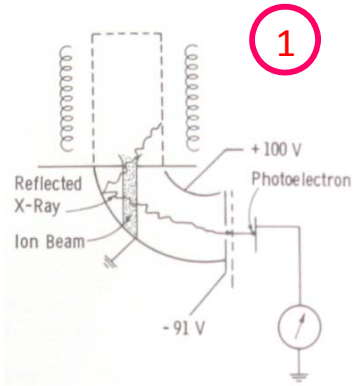
- Pressure limit ~ 10^{-14} mbar C. Benvenuti and M. Hauer. 8th IVC, Cannes (1980)

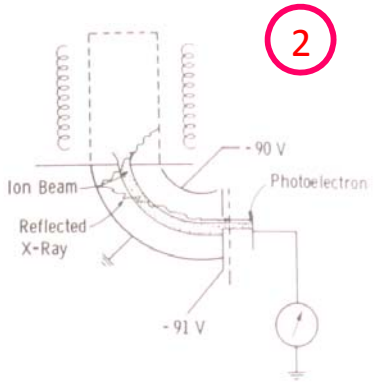


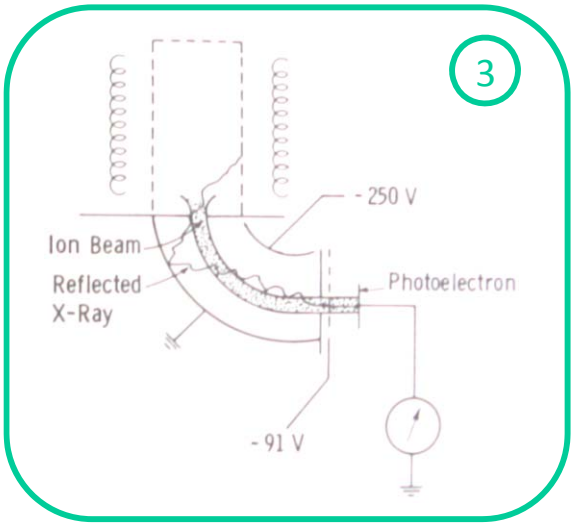
J.C. Helmer and W.H. Hayward. Rev. Sci. Instrum., 37, 1652, (1966)

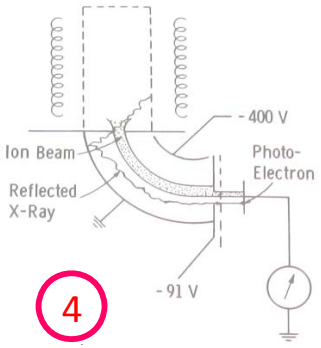
Principle of deflection in a Helmer vacuum gauge

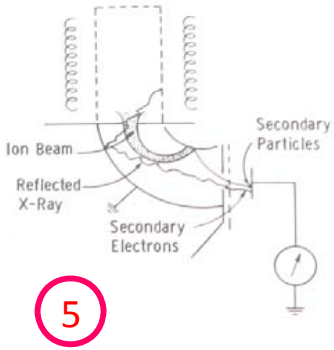








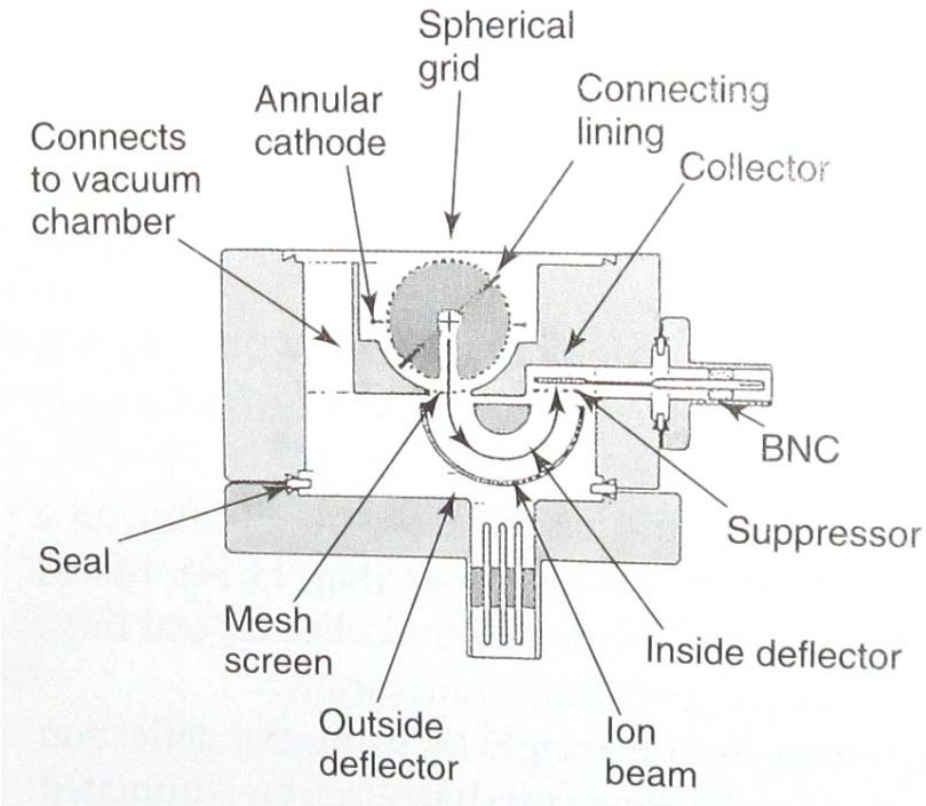




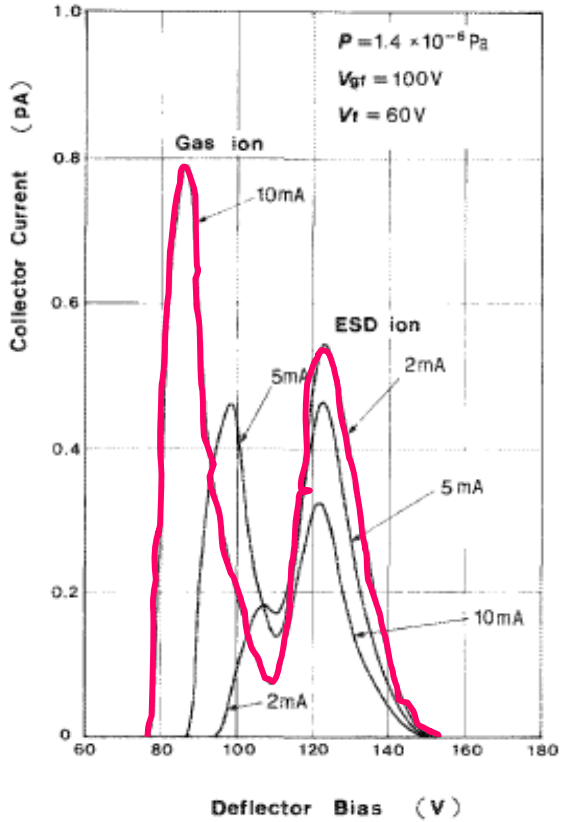
Helmer gauge and electronic manual- Varian - 1967

Ion spectroscopy gauge

- It is a refined Helmer gauge with a spherical analyser (better ion convergence)
- The 180° deflection unit is used as an energy filter
- Electron space charge in the ions source generates a large kinetic energy difference between ions
- Ions from gas phase are easily discriminated from ions produced at the grid by ESD
- Pressure limit < 10^{-14} mbar F. Watanabe. JVSTA A11(4) Jul/Aug 1993, 1620



Handbook of vacuum technology, Ed. K. Jousten, Wiley-VCH, 2008



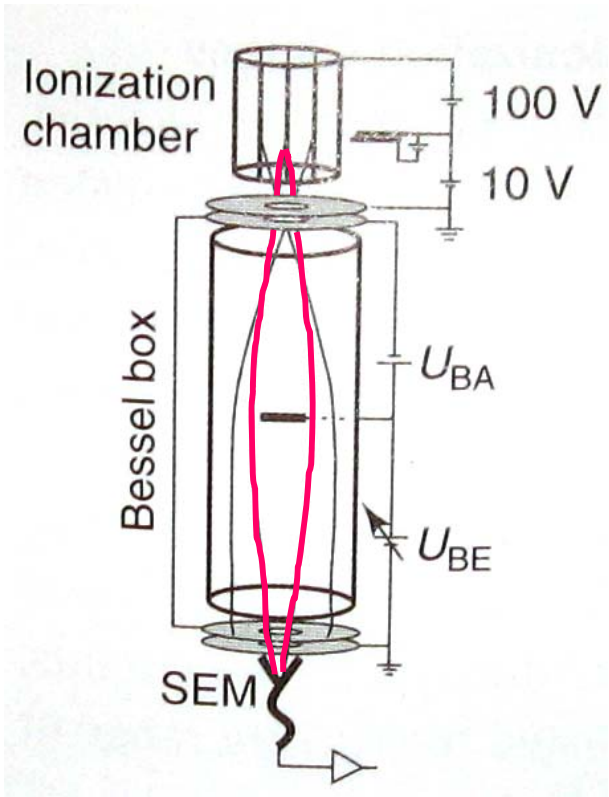
F. Watanabe. JVSTA A10(5) Sep/Oct 1992, 3333

Bessel box – AxTRAN gauge

- A center disk screens the ion collector from X-rays
- A Bessel box type analyser allows to discriminate ions from gas phase and ESD
- Ions collected from the gas phase are produced at the central region of the grid where the potential is about 30 V less than the grid

- Pressure limit 5 10^{-14} mbar

ULVAC Technologies, Inc.
401 Griffin Brook Drive
Methuen, MA 01844



Handbook of vacuum technology,
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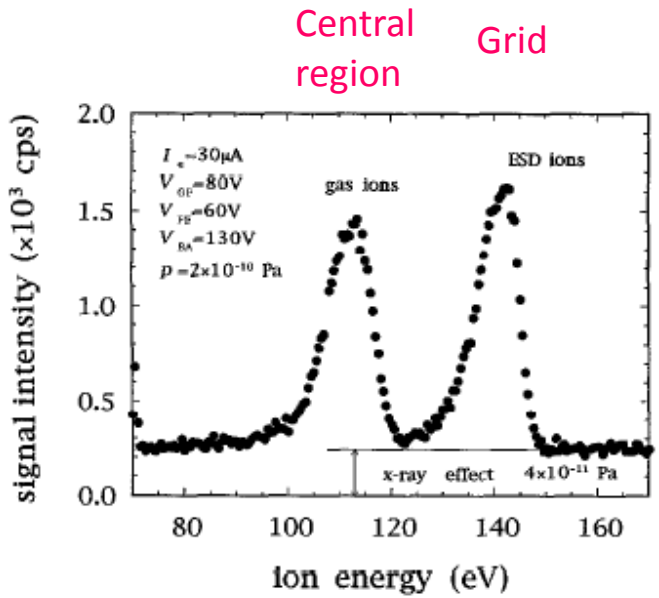


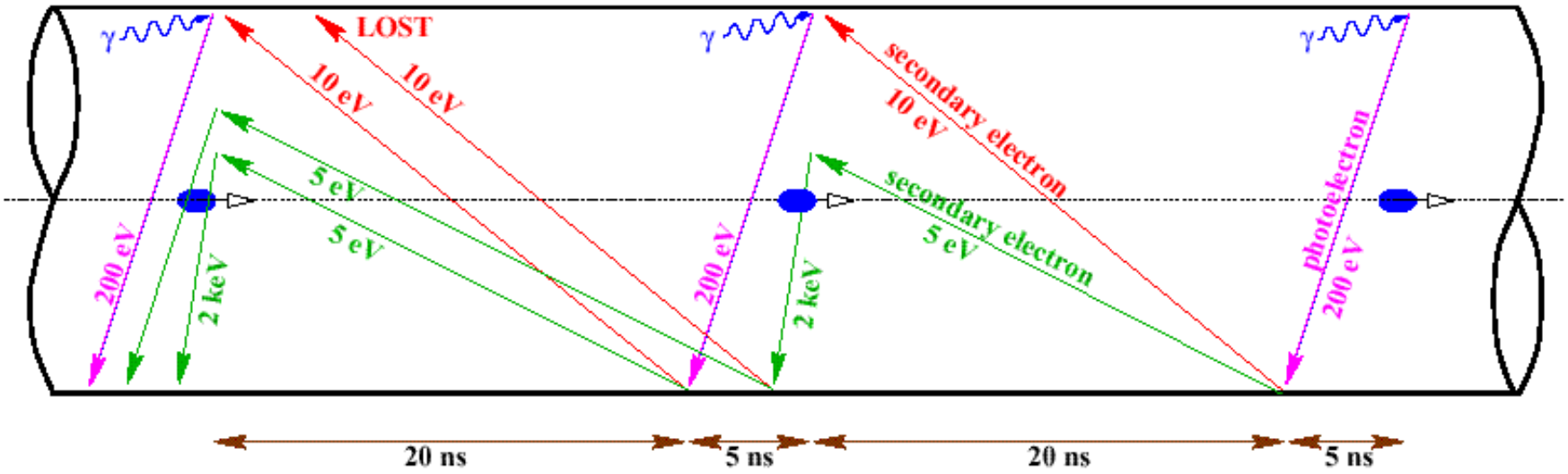
Figure 4. Ion energy spectrum obtained at a pressure of 2×10^{-10} Pa (N_2 eq.). The background signal, 249 counts s^{-1}, is the X-ray photocurrent, and is equivalent to 4×10^{-11} Pa (N_2 eq.). The signal intensities of the gas phase and ESD ions at 30 μA in emission current, from which background signals are subtracted, are 1200 and 1400 counts s^{-1}, respectively.

H. Akimichi *et al.* Vacuum, 46, 749 (1995)

2. Instruments in machines

Electron Cloud in the CERN Large Hadron Collider: the Mecanism

- In modern machine with dense bunches and large positive current : KEK-B, PEP-II, SPS, RICH, LHC …
- Emittance growth, gas desorption and heat load in cryogenic machine
- Key parameters :
  - bunch structure
  - vacuum chamber dimension
  - secondary electron yield (SEY)
  - photon electron yield
  - electron and photon reflectivity
  - …

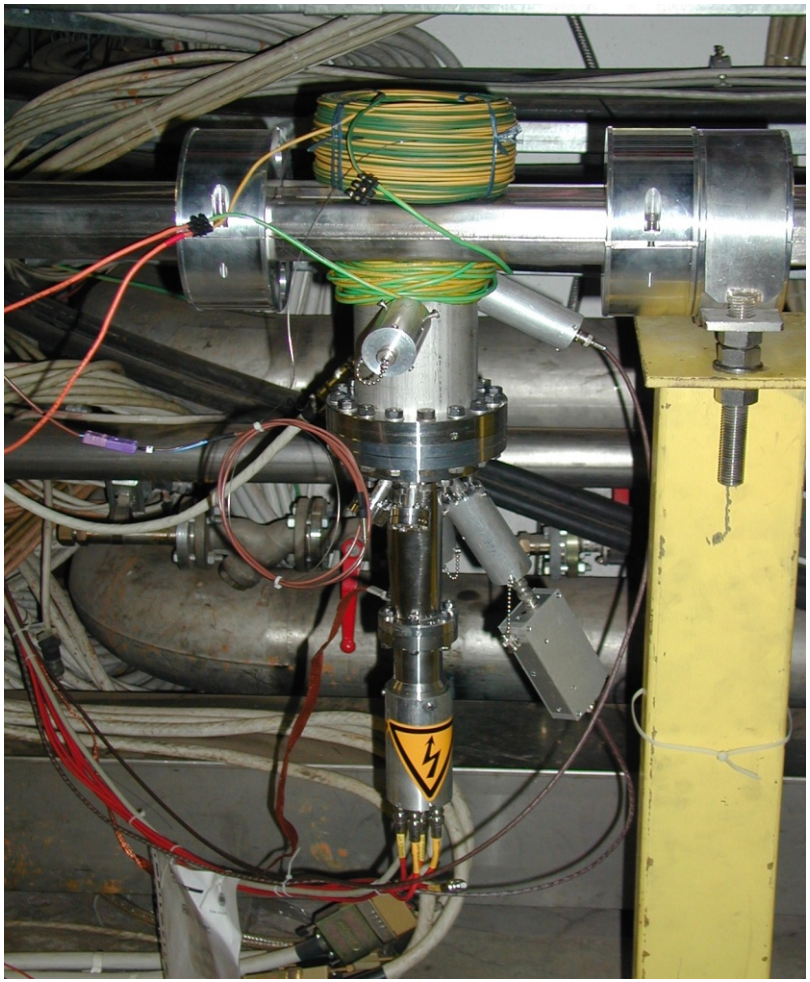


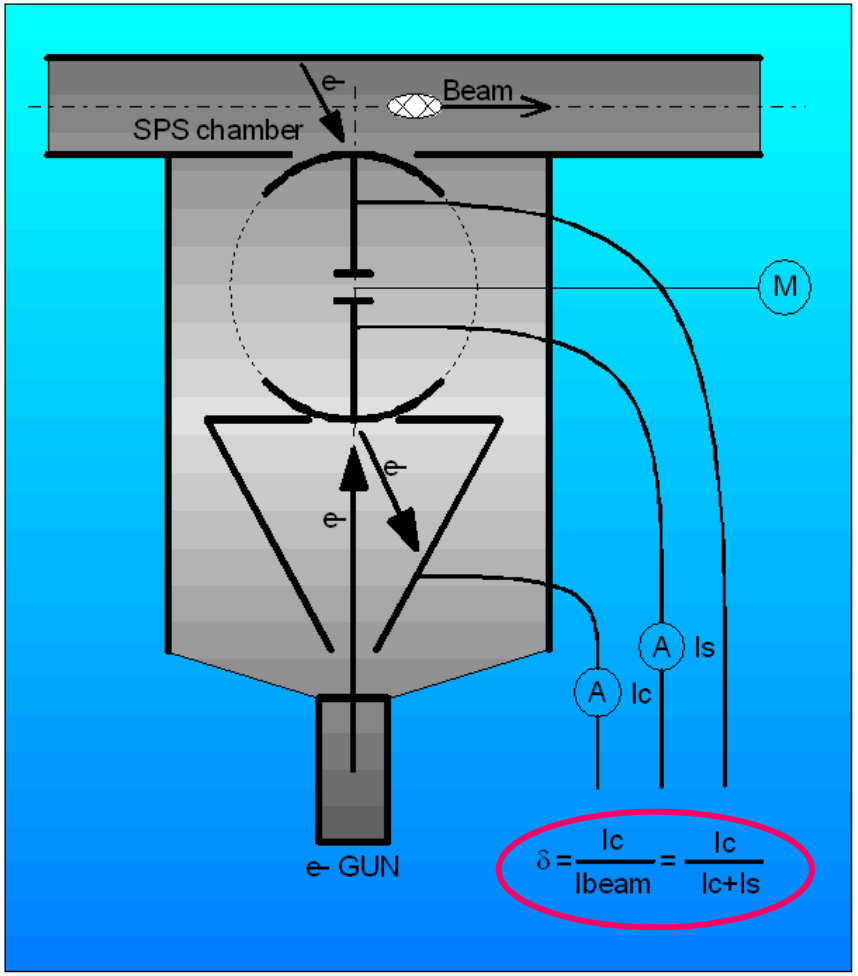
Schematic of electron-cloud build up in the LHC beam pipe.

F. Ruggiero *et al.,* LHC Project Report 188 1998, EPAC 98

In-situ SEY

- Allows to follow electron cloud process in the machine

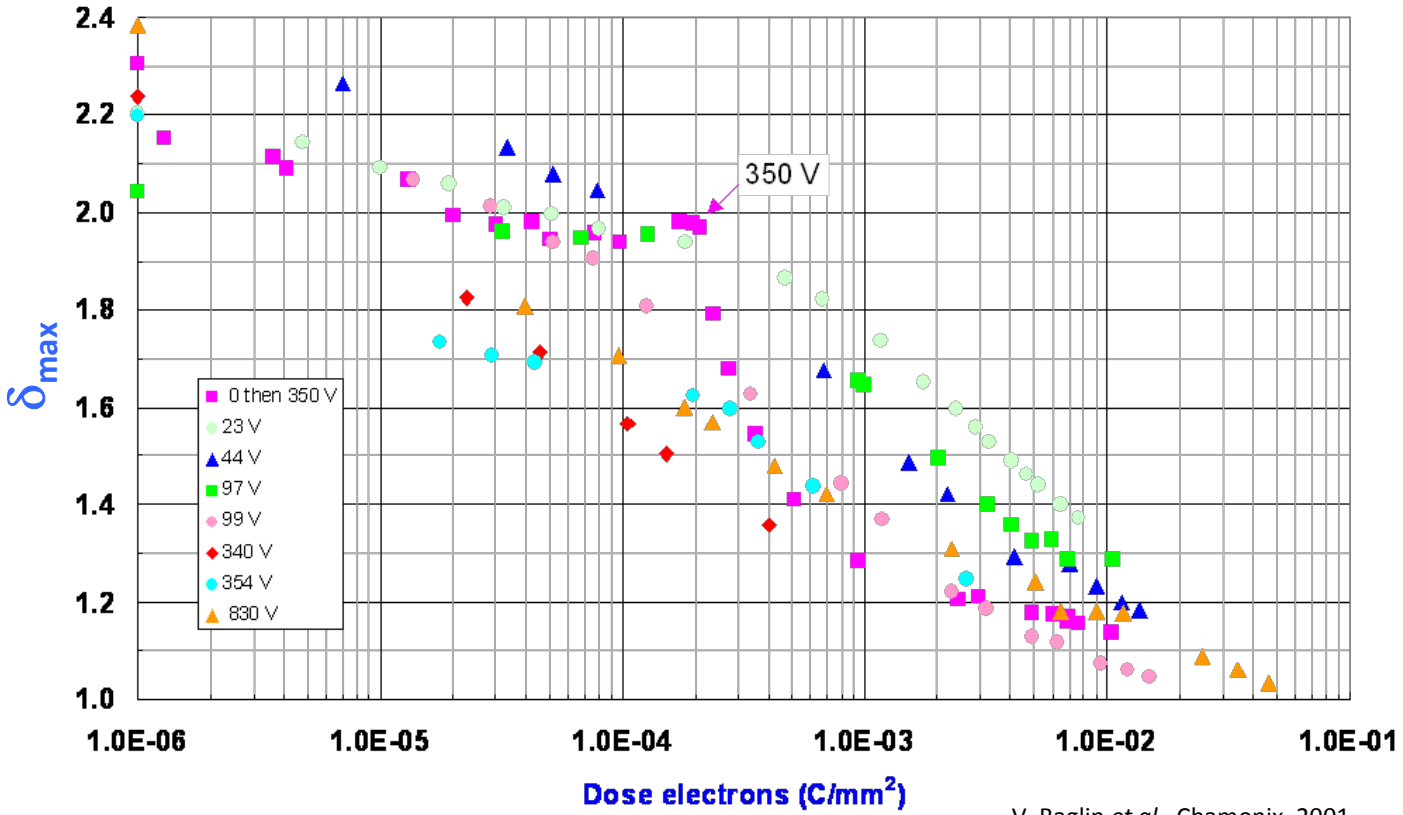




Courtesy B. Henrist, N. Hilleret CERN TE-VSC

In-situ SEY … consequence

- LHC operation at high current is based on photon and electron conditioning
- About 10 mC/mm^2 required to reach δ_{max} equals 1.2

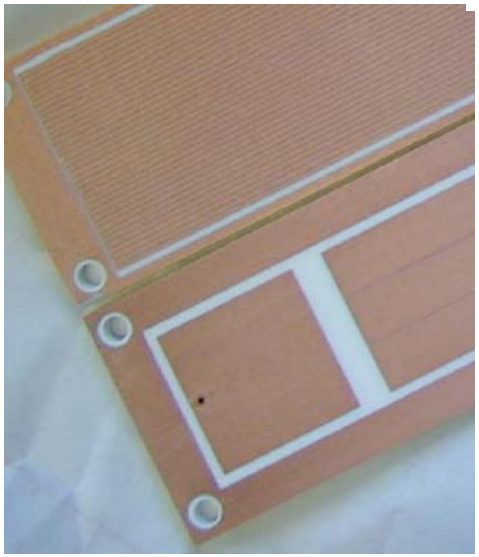


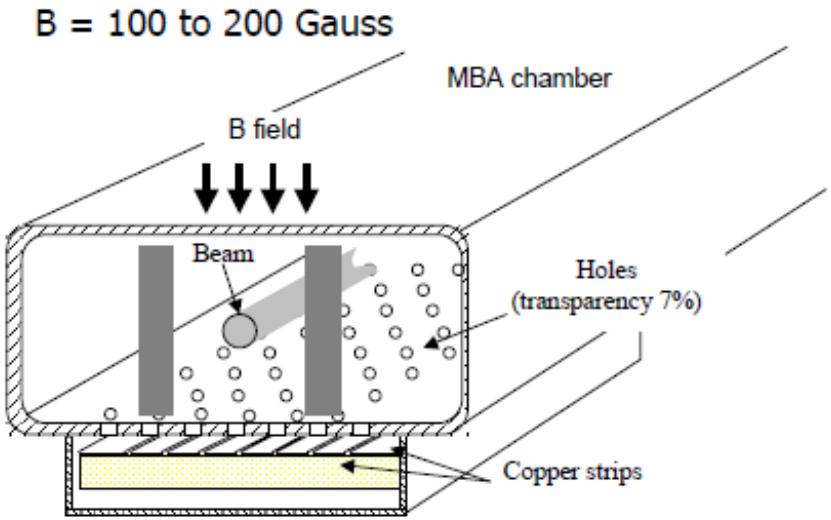
V. Baglin *et al.*, Chamonix, 2001

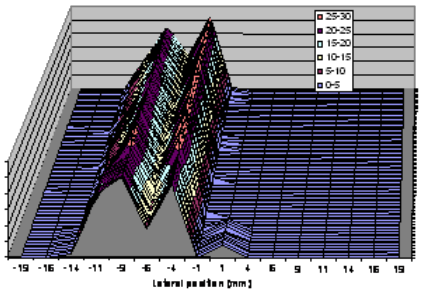
Spatial resolution

- Current measured on a biased strip
- Allows to check electron cloud simulation

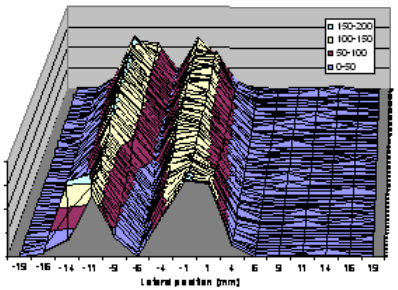
J.M. Jimenez *et al.* Proceedings of EPAC 02, Paris



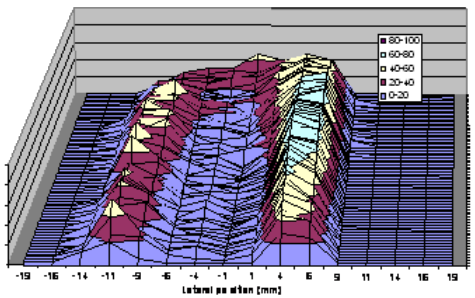




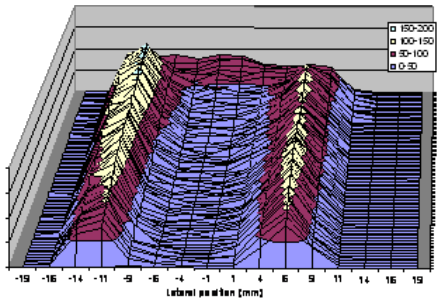
5.0×10^{10} p/b



6.0×10^{10} p/b



7.9×10^{10} p/b

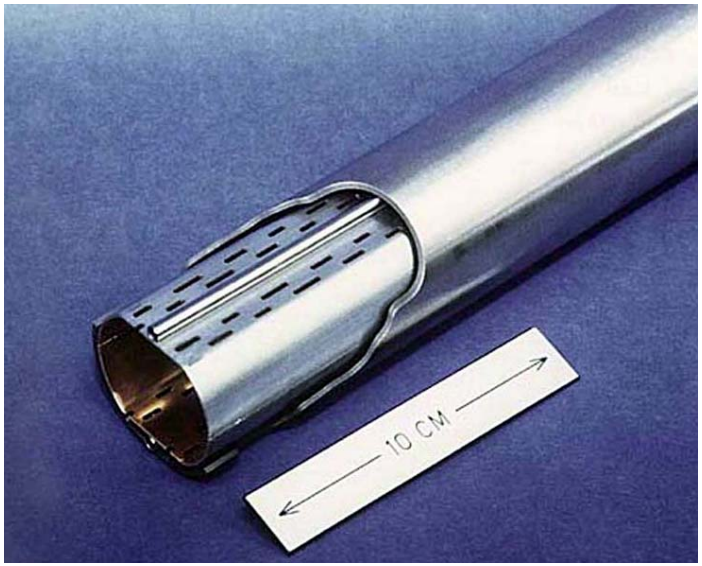


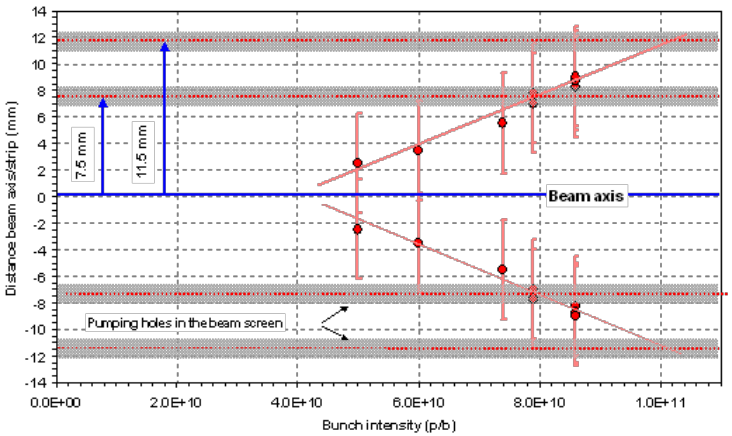
8.6×10^{10} p/b

Spatial resolution … consequence

- Electron cloud shield located outside the LHC dipole beam screens
- Ensures the thermal protection the 1.9 K magnet cold bore of a 7 TeV machine against few 100 eV electrons

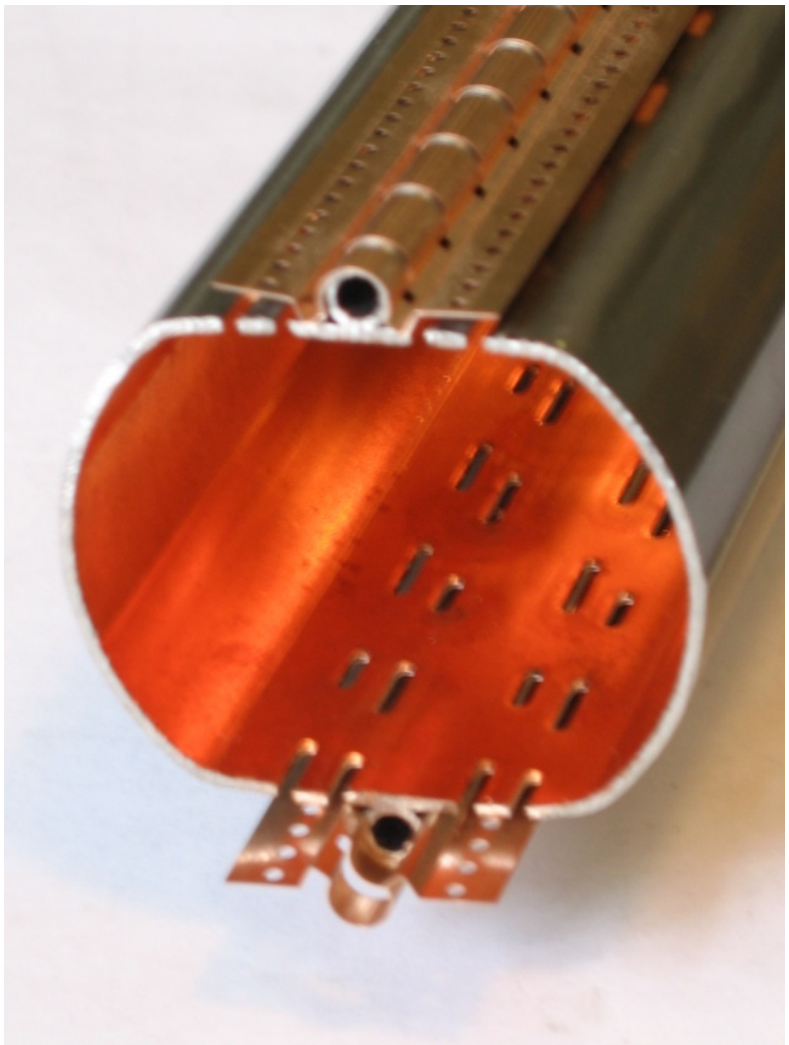
Courtesy N. Kos CERN TE/VSC





J.M. Jimenez *et al.* CERN LHC Project Report 632

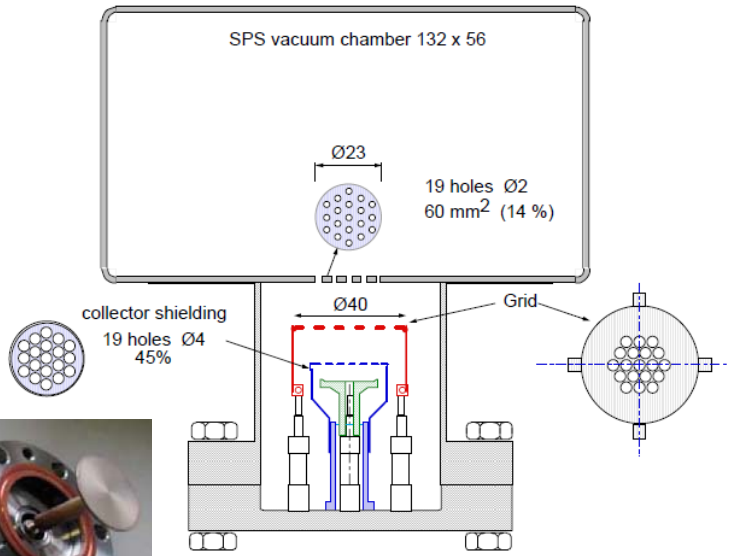
LHC Design

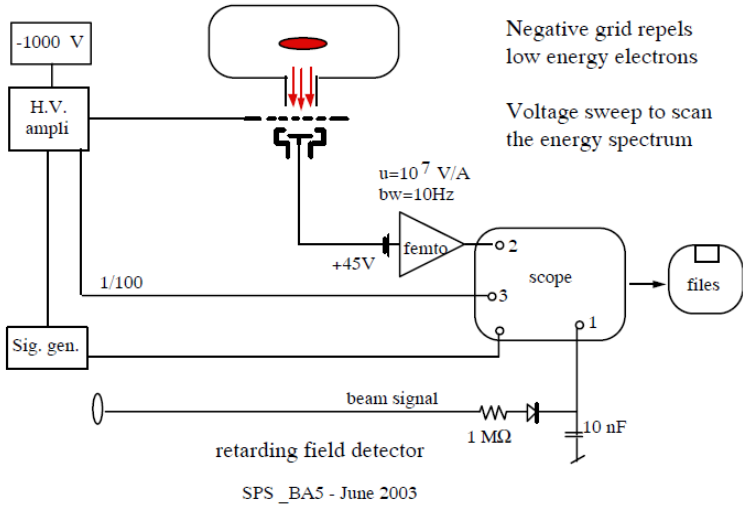


Courtesy N. Kos CERN TE/VSC

Energy analyser in accelerators : retarding field detector

Courtesy J.M. Laurent, CERN TE-VSC



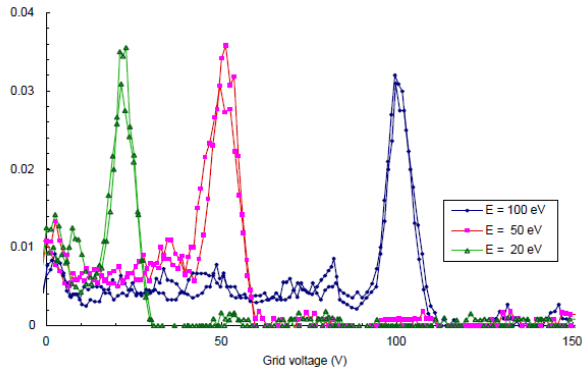


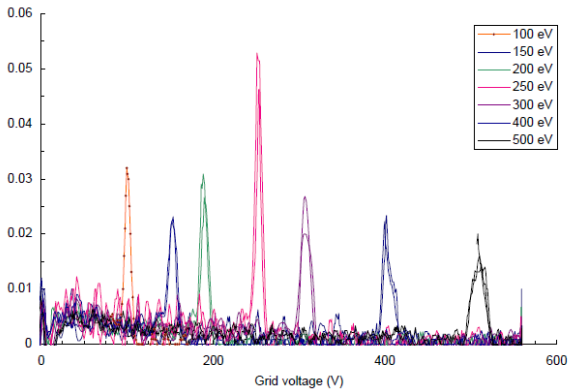
The voltage of the grid is swept from 0 to 1 kV while the beam is present. The energy spectrum of the electrons can be deduced from the derivative of the collected current versus time

Electron current

Beam

Grid voltage

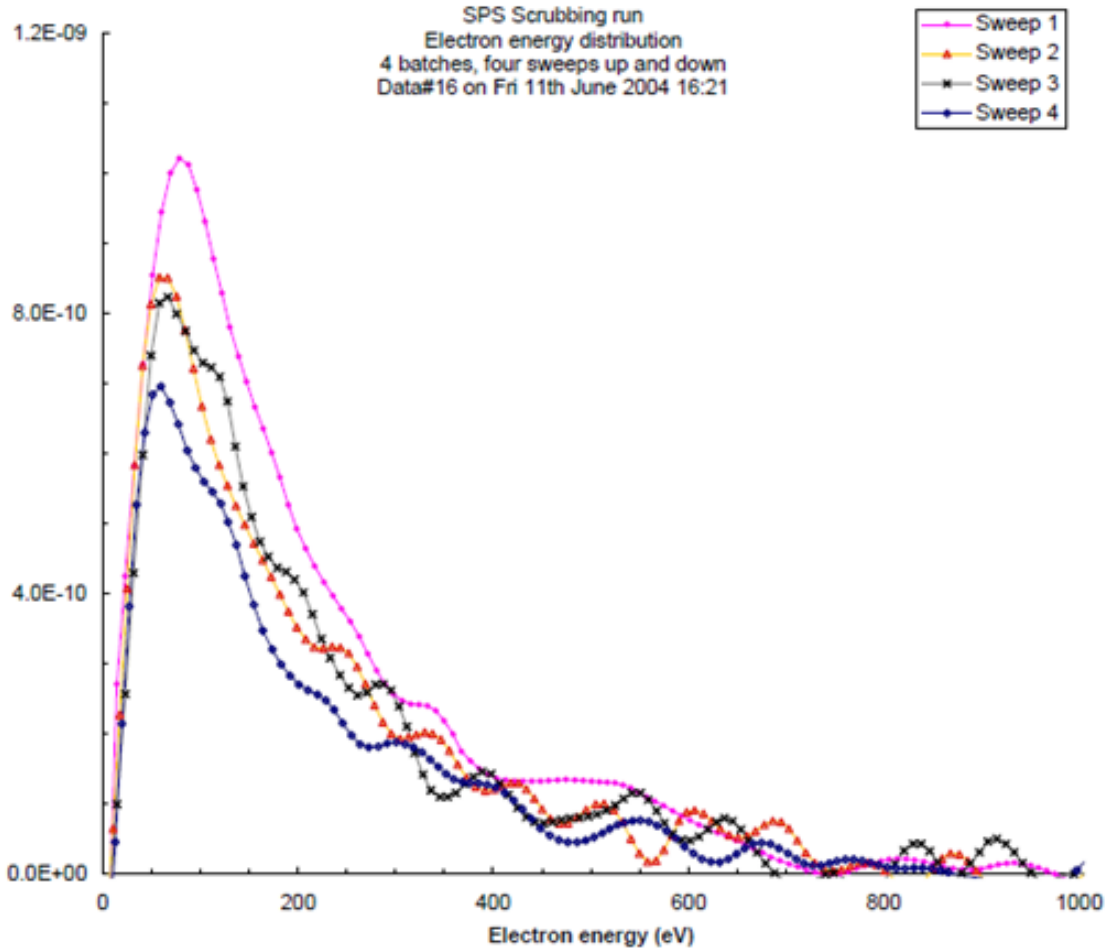




Laboratory calibration

Distribution of electron energies

Maximum of energy distribution around 100 eV
Electrons with energies as high as 600 eV still visible



Courtesy J.M. Laurent, CERN TE-VSC

Another energy analyser in accelerators : RHIC case

W. Fisher, U. Iriso *et al*. Phys. Rev. ST Accel. Beams 11, 041002 (2008)

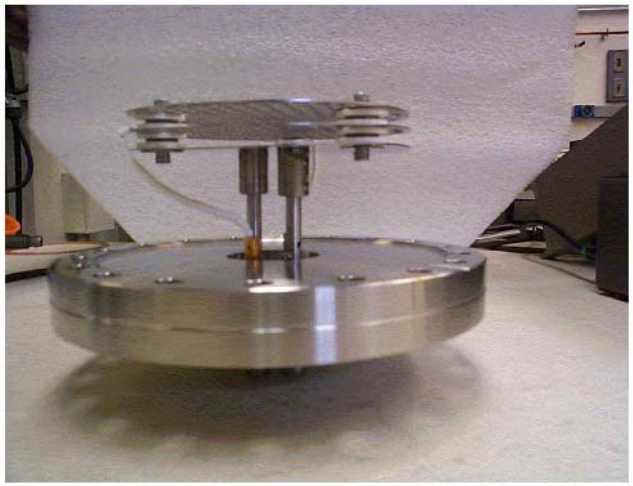
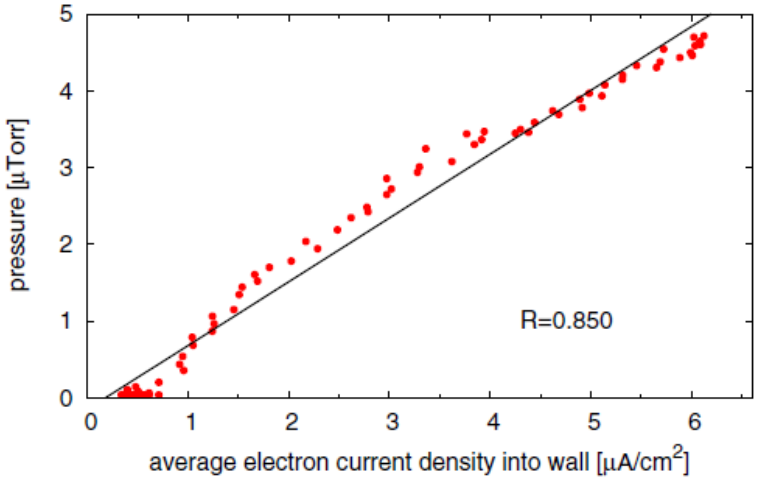


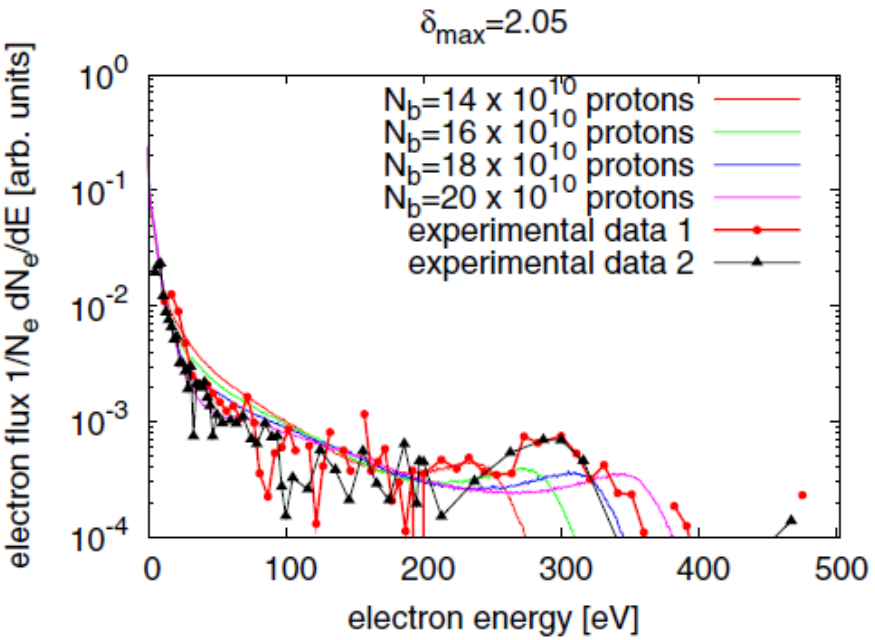
FIG. 7. (Color) Multigrid electron detector in RHIC. The grids have a diameter of 12 cm [43].



Correlation between pressure and electron current : ESD

- Major contribution of low energy electron below 10 eV
- Energy extend to 300 eV
- Electrons below 5 eV cannot be measured

- The spectrum shape does not depend of δ_{max} but depends on the beam parameters (bunch intensity, length, etc.

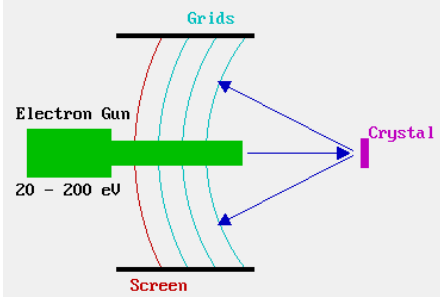


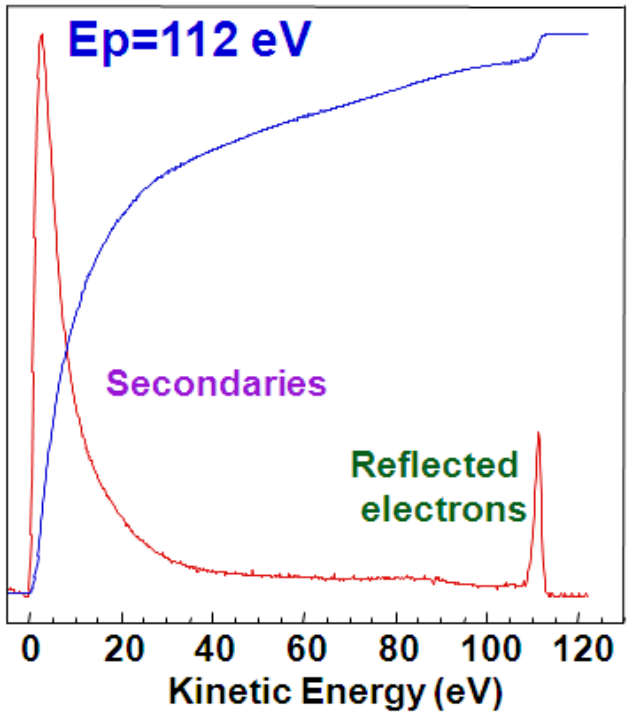
3. Future instruments

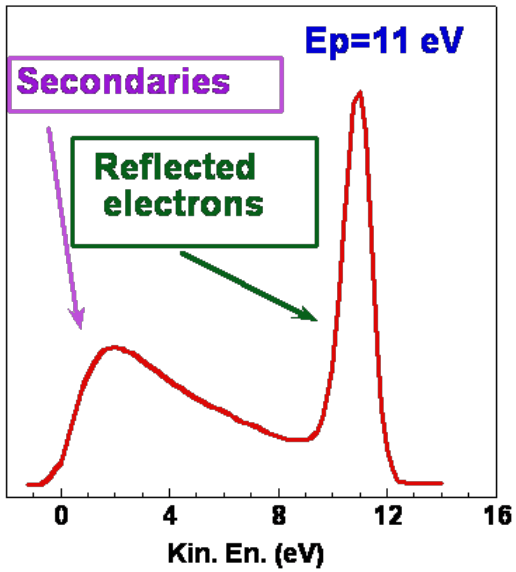
Low Energy Electron Diffraction detector in the laboratory

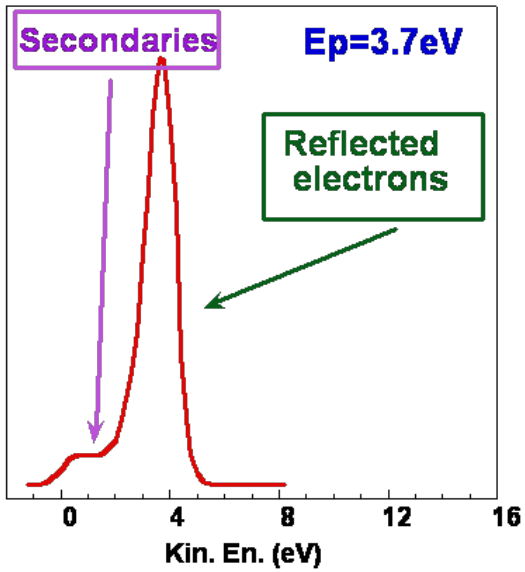
- Measures energy distribution curves as a function of $E_{primary}$

Omicron Vakuumphysik GMBH





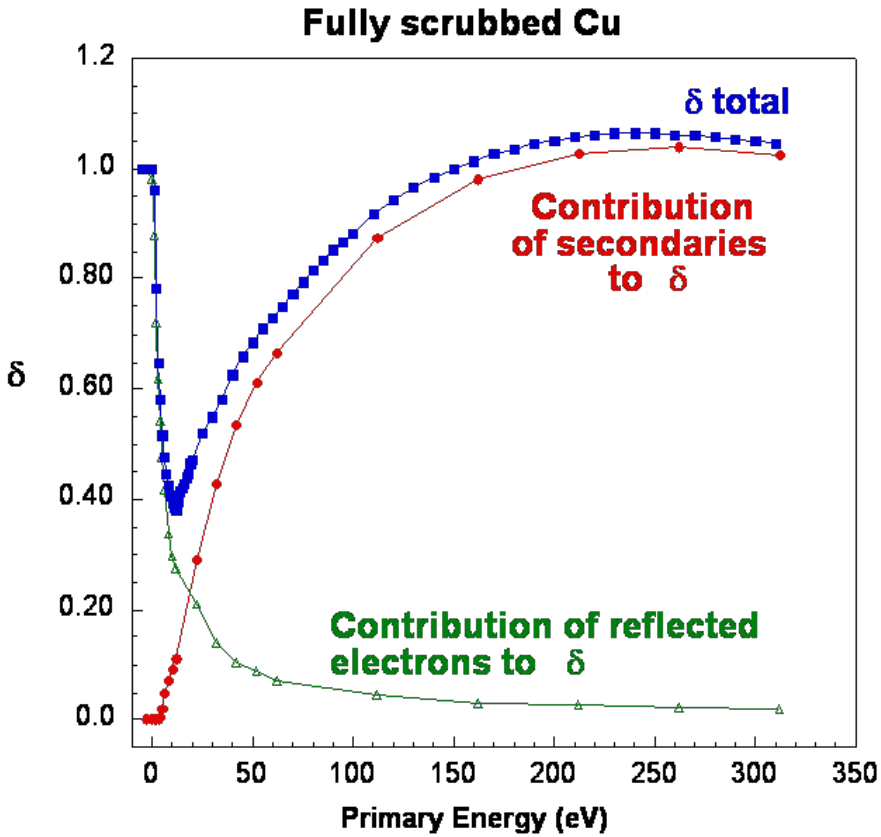


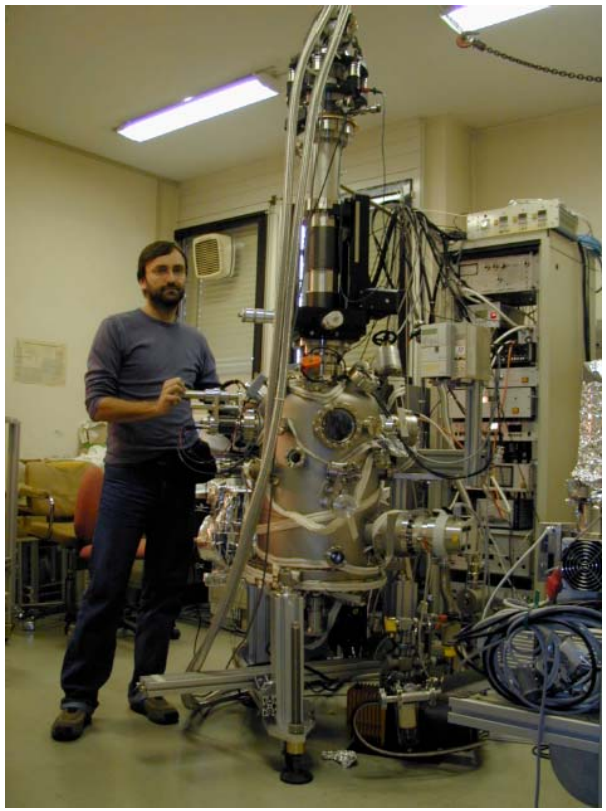


R. Cimino , I.R. Collins, App. Surf. Sci. 235, 231-235, (2004)

LEED in the laboratory

- To study the secondary electron yield curve of copper samples held at cryogenic temperature

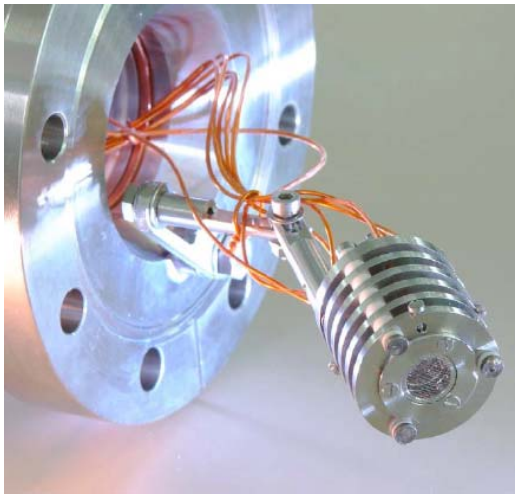


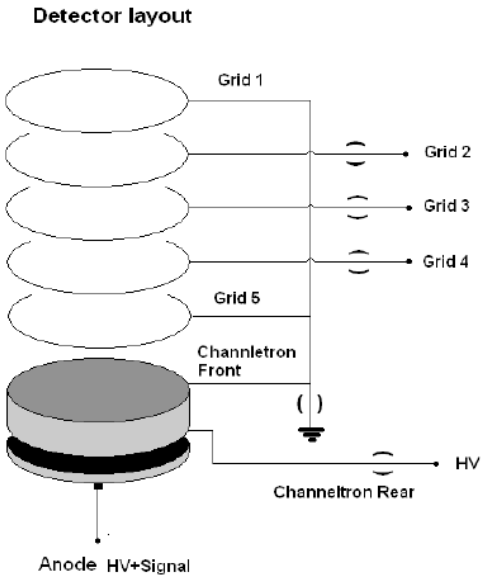


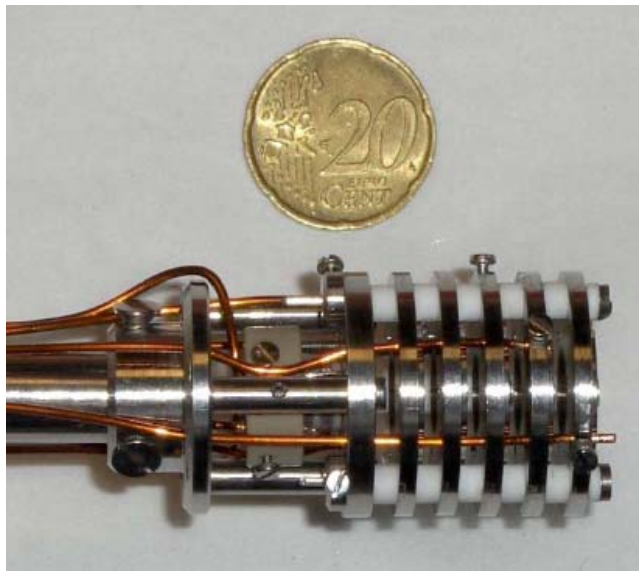
R. Cimino , I.R. Collins, App. Surf. Sci. 235, 231-235, (2004)

Towards LEED in the accelerator

- The LNF-retarding field analyser is based on LEED-Auger optics



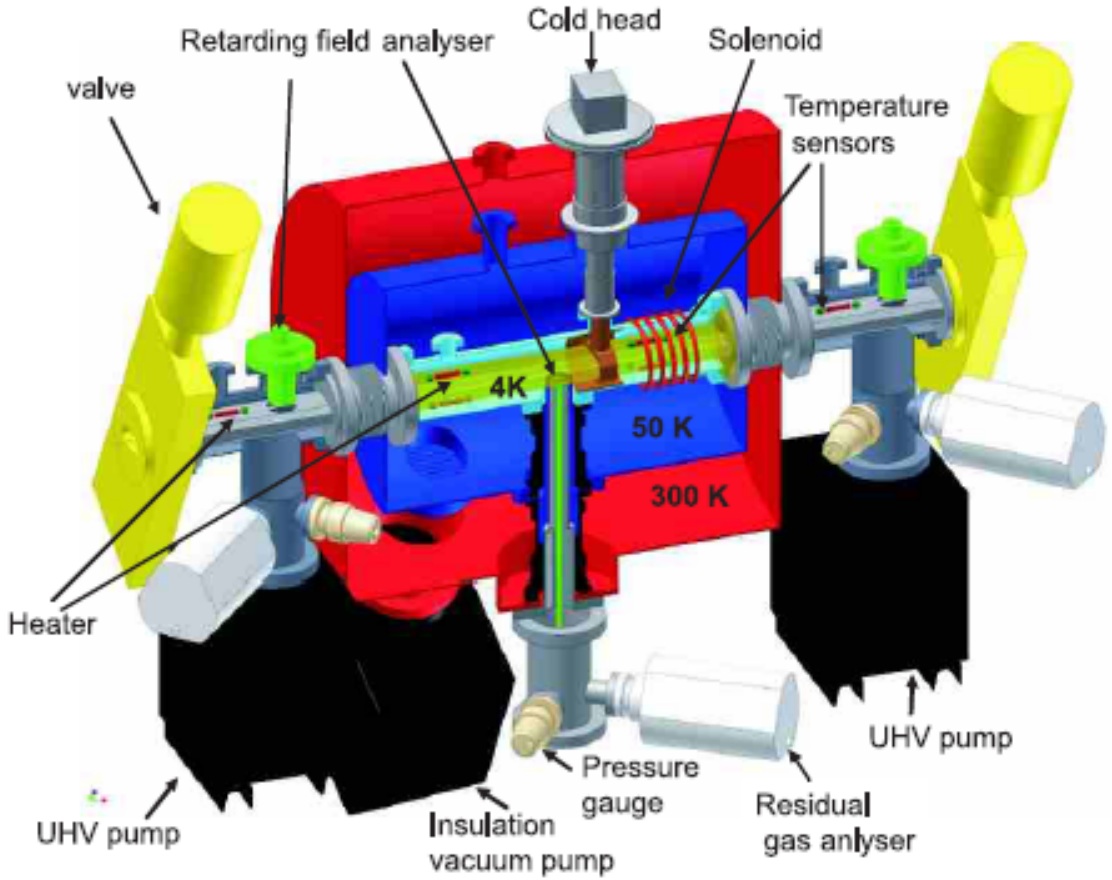




M. Commisso, R. Cimino et al. Proceedings of EPAC 2008, Genoa

Towards fully instrumented cold vacuum chamber

- Design to study superconducting wigglers and electron cloud interaction
- Comparison between room temperature and cryogenic environment
- Energy analyser
- Total and partial pressure measurements
- Heat load measurement and calibration
- Solenoid to suppress electron cloud



S. Casalbuoni et *al.* Proceedings of EPAC 2008, Genoa

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Thank you for your attention !!!