

Simulation Studies of Electron Cloud in the Experimental Regions of the LHC

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Outline

- Motivations
- Experimental beam pipe geometry
- TiZrV Non Evaporable Getter coating
- Electron cloud simulations parameters
- Electron cloud simulations results
- Gas density estimations
- Code benchmarking
- NEG experiments in the SPS

Motivations

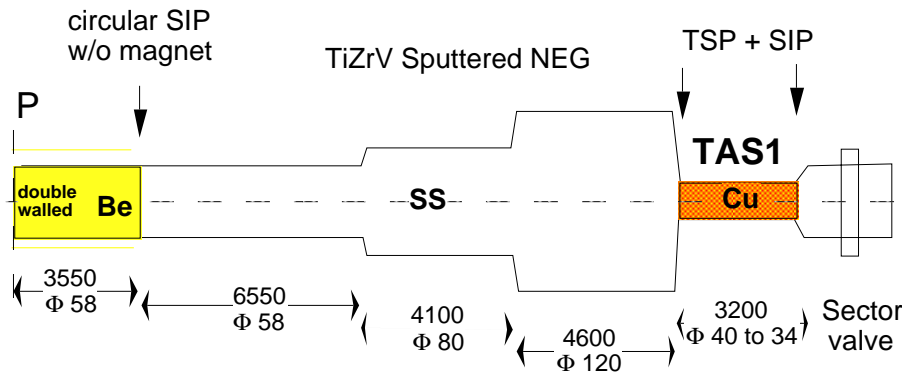
Electron multipacting in the experimental regions

- Variable geometry, non uniform magnetic fields, two beams.
- Establish a criterion for **maximum allowable SEY**
 - Beam stability and emittance: what is the **maximum length** where electron cloud can be tolerated?
 - Vacuum: residual **gas density** from electron stimulated desorption?

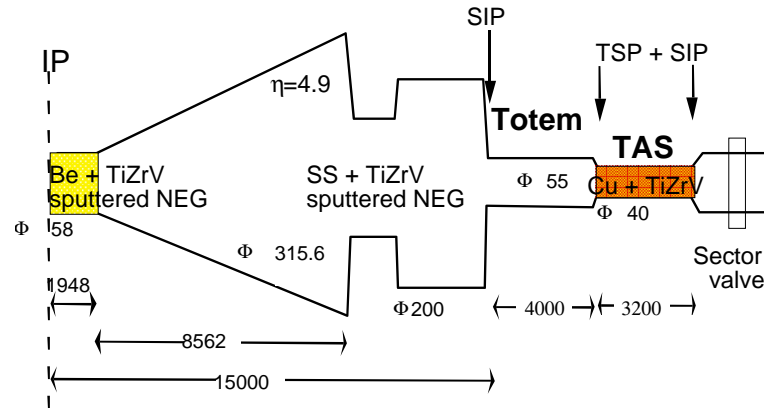
(In the LHC arcs determined by max power onto cold bore)

Experimental beam pipe geometry

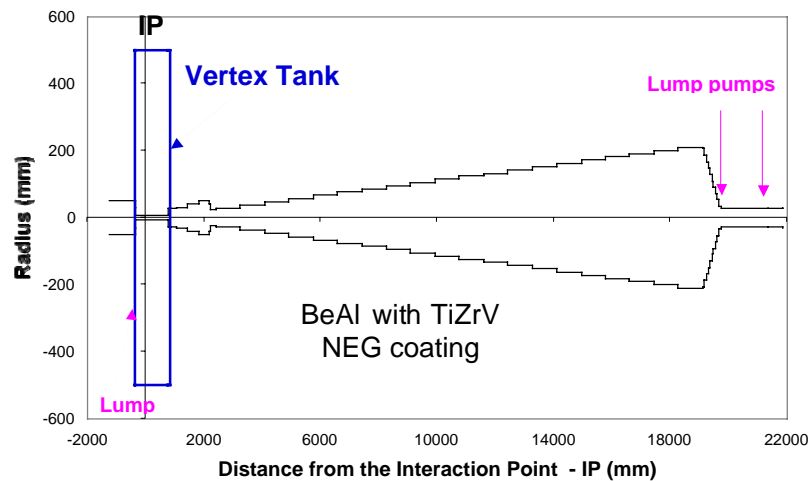
ATLAS



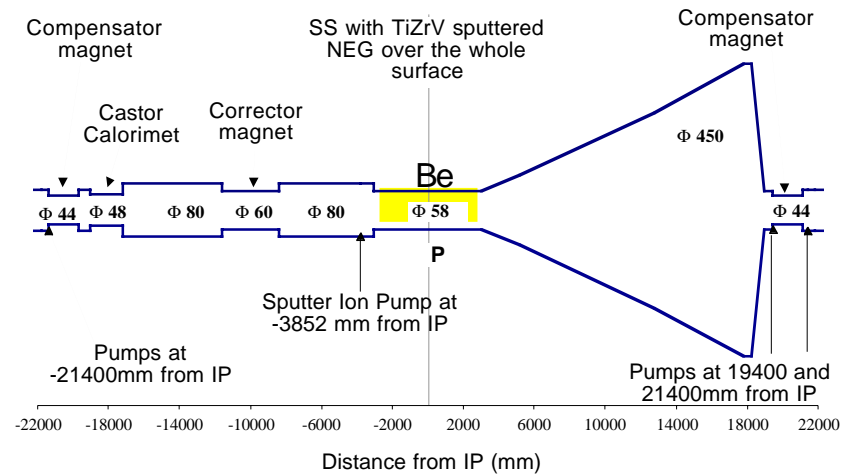
CMS-TOTEM



LHCb



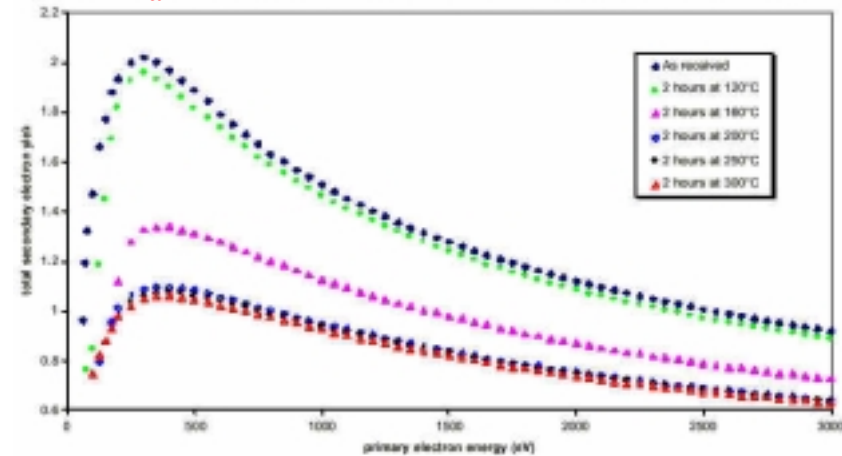
ALICE



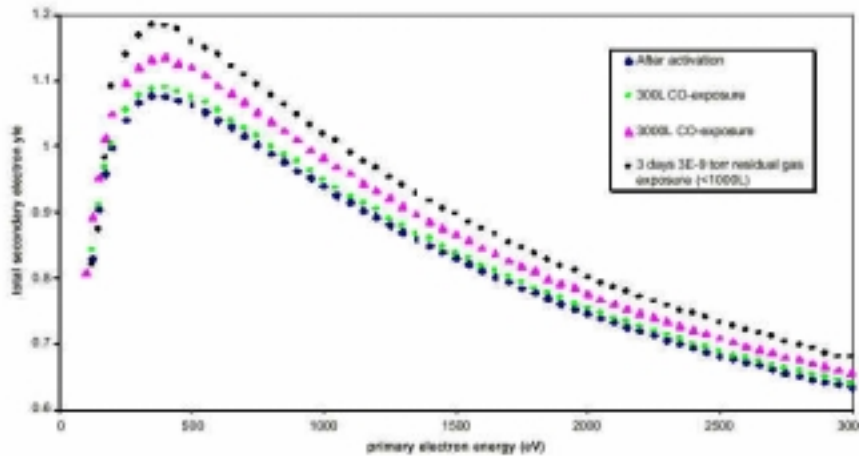
Non-Evaporable TiZrV getter coating

- Baseline design for LHC experimental beam pipes (low mass pumping for H₂, CO and CO₂)
 - ◆ to guarantee vacuum stability
 - ◆ to **limit multipacting**
 - ◆ to limit background pressure.
- Indispensable for Be and Al chambers
- Baseline design for LHC warm LSS.

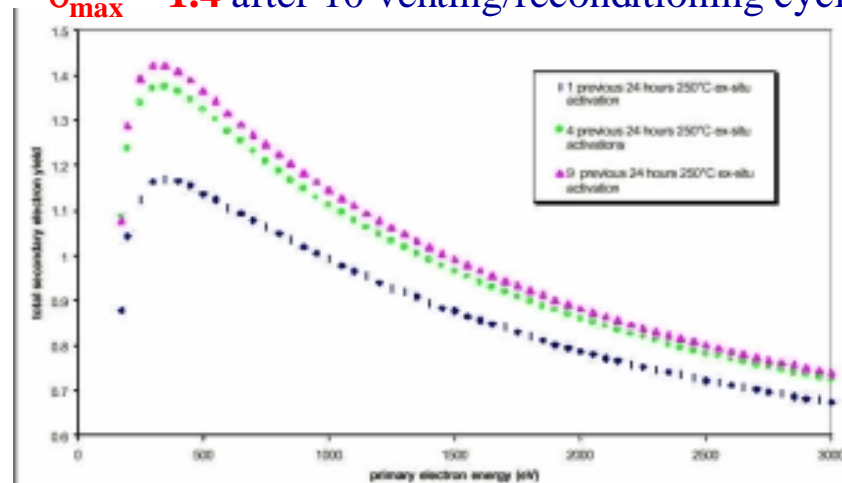
$\delta_{\max} \sim 1.1$ after 2 h activation at 200 °C.



$\delta_{\max} < 1.2$ after exposition to CO.



$\delta_{\max} \sim 1.4$ after 10 venting/reconditioning cycles.



B. Henrist, N. Hilleret, Ch. Schuerlein, CERN, Vacuum Tech. Notes 1998

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Electron cloud simulation parameters

- Proton beam parameters:
 - Nominal energy (7 TeV)
 - Nominal intensity ($1.05 \cdot 10^{11}$ protons/bunch) with
 - double intensity and 7.48 m bunch spacing



- Single intensity and 3.74 m bunch spacing

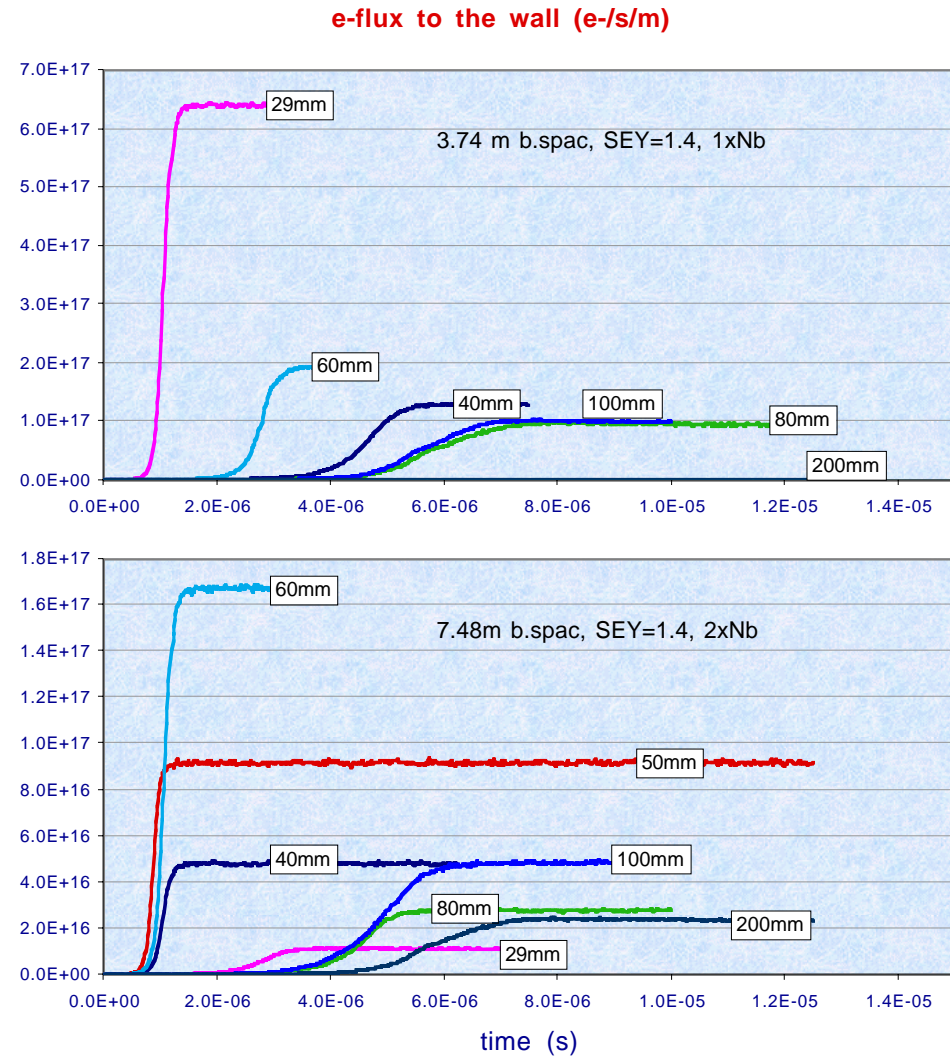


- Geometry: radii from 22 mm to 200 mm
- Field free regions
- SEY from 1.1 to 1.4
- Primaries = photoelectron
- Reflection as for Cu

Electron cloud simulation results

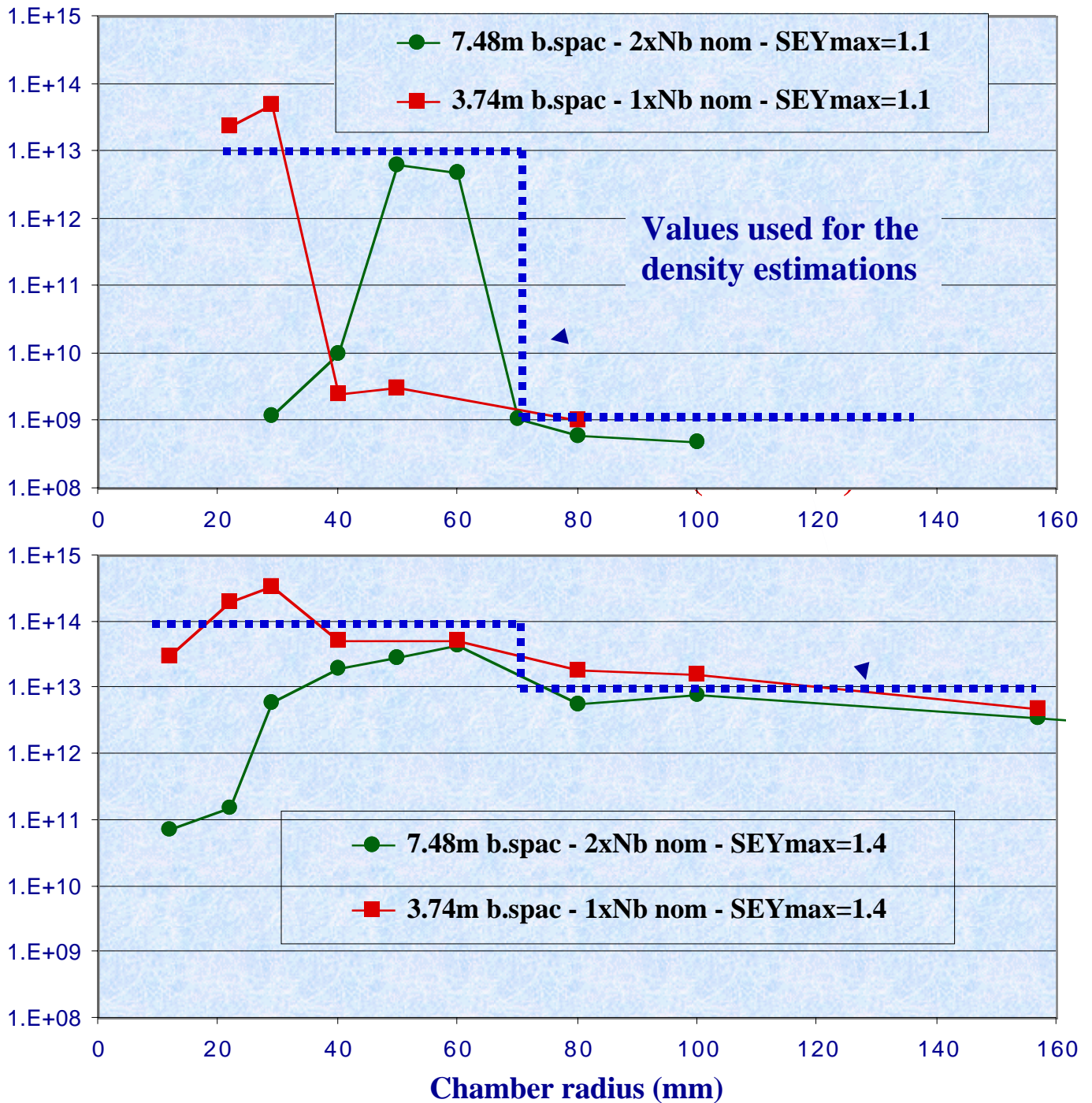
Dependence on the chamber radius:

- e- wall flux and density at saturation
- rise time



Electron cloud simulation results

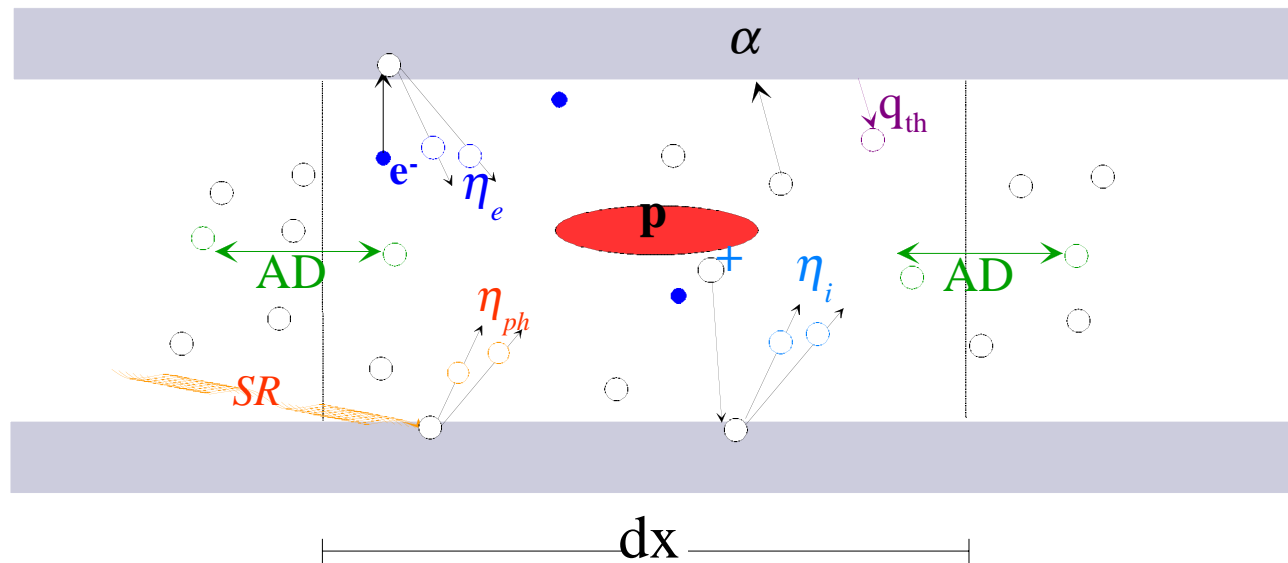
e- flux to the wall e/cm²/s



Residual gas density

Simulations code

- Cylindrical geometry
- Time invariant parameters
- Finite elements
- Proton beam induced phenomena : ion (negligible), electron and photon stimulated molecular desorption



Residual gas density

Simulations parameters

- Photon flux to the wall estimated 10^{16} ph/m/s (O.Malyshev)
- Electron flux as from simulations

Gas	TiZrV PSD ^[1]	TiZrV ESD ^[2]	TiZrV ^[3] sticking at SEY=1.4	TiZrV ^[3] sticking at SEY=1.4
H ₂	$2.50 \cdot 10^{-7}$	$2.0 \cdot 10^{-4}$	$5.0 \cdot 10^{-3}$	$5.0 \cdot 10^{-4}$
CH ₄	$2.50 \cdot 10^{-9}$	$5.0 \cdot 10^{-6}$	0	0
CO	$1.25 \cdot 10^{-8}$	$1.0 \cdot 10^{-4}$	$1.0 \cdot 10^{-1}$	$1.0 \cdot 10^{-2}$
CO ₂	$1.25 \cdot 10^{-8}$	$1.0 \cdot 10^{-4}$	$1.0 \cdot 10^{-1}$	$1.0 \cdot 10^{-2}$

Values obtained
on other materials
after > 1year
LHC operations

High pumping
available

[1] V. Baglin et al., corrected for grazing incidence and 12eV critical energy

[2] P.Chigiato et al., ~500eV incident energy

[3] C.Benvenuti et al.

Electron cloud simulation results

Gas density estimations ESD at 500eV
(available for TiZrV).

Considering experimental data spread and
weak dependence on energy > 100 eV

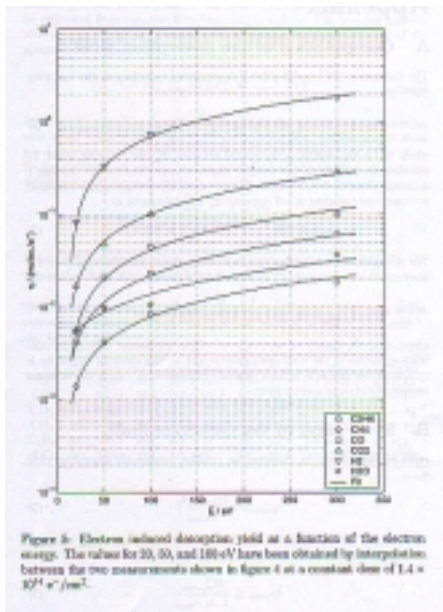
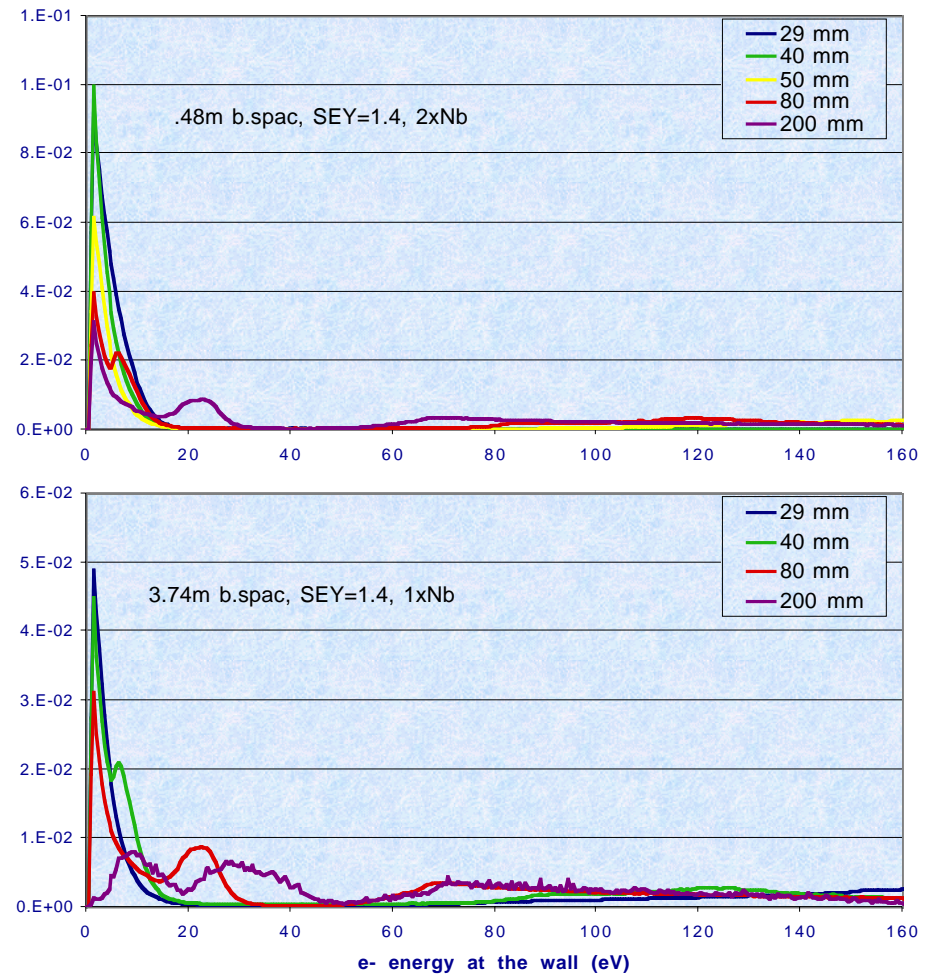


Figure 5: Electron induced desorption yield as a function of the electron energy. The values for 20, 50, and 100 eV have been obtained by interpolation between the two measurements shown in figure 4 at a constant dose of 1.4 $\times 10^{11}$ e⁻/cm².

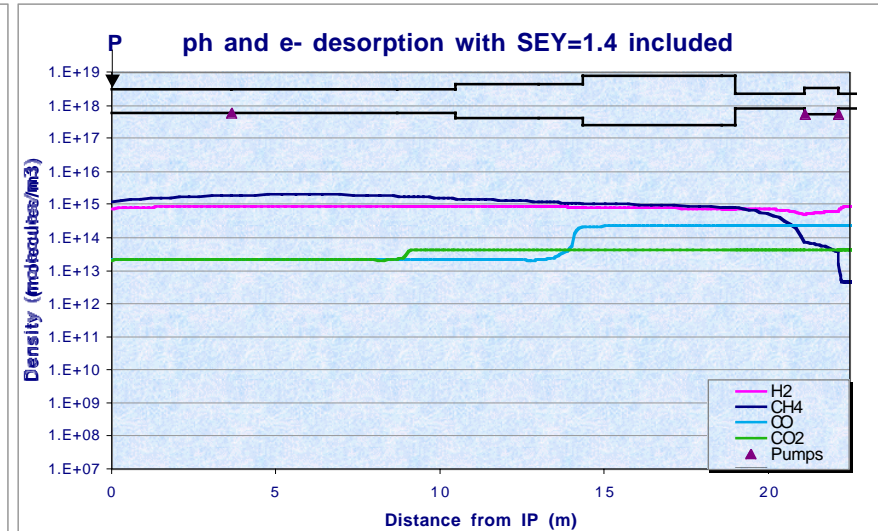
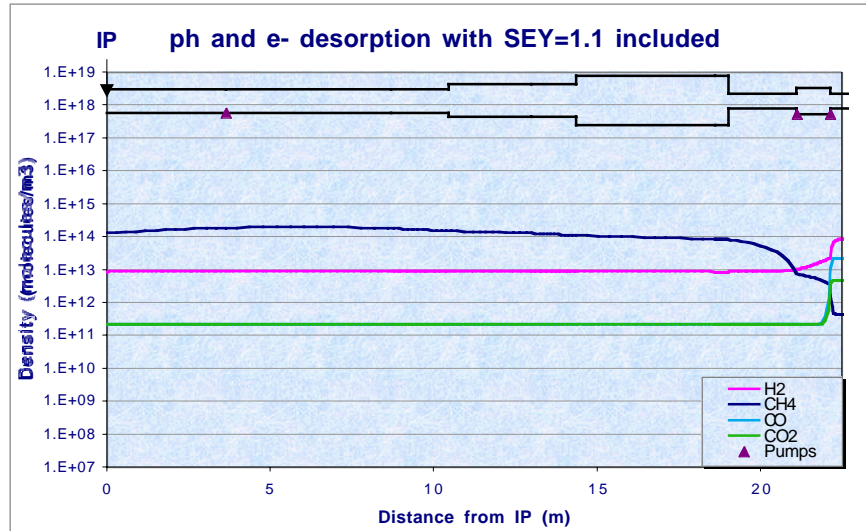
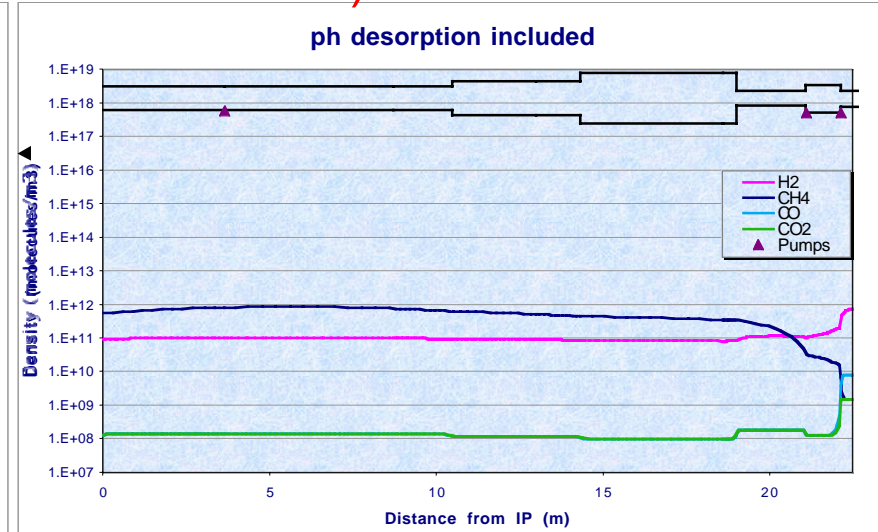
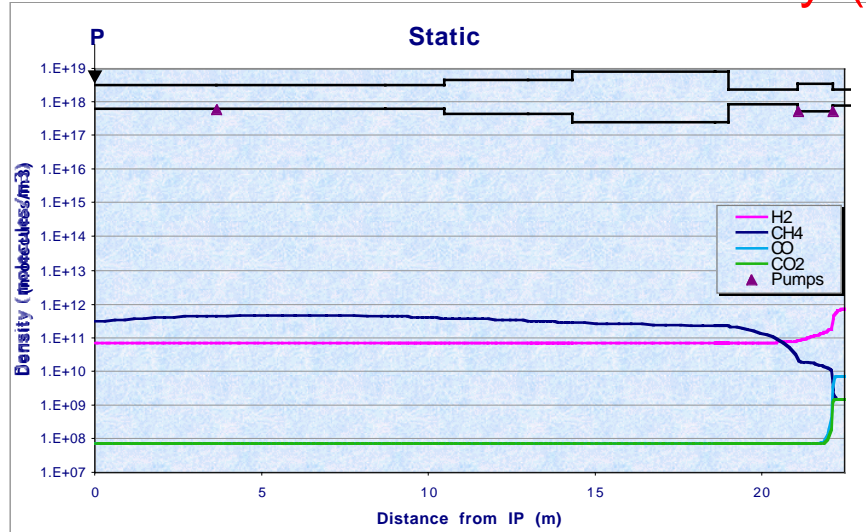
G. Vorlauffer et al.

Energy distribution



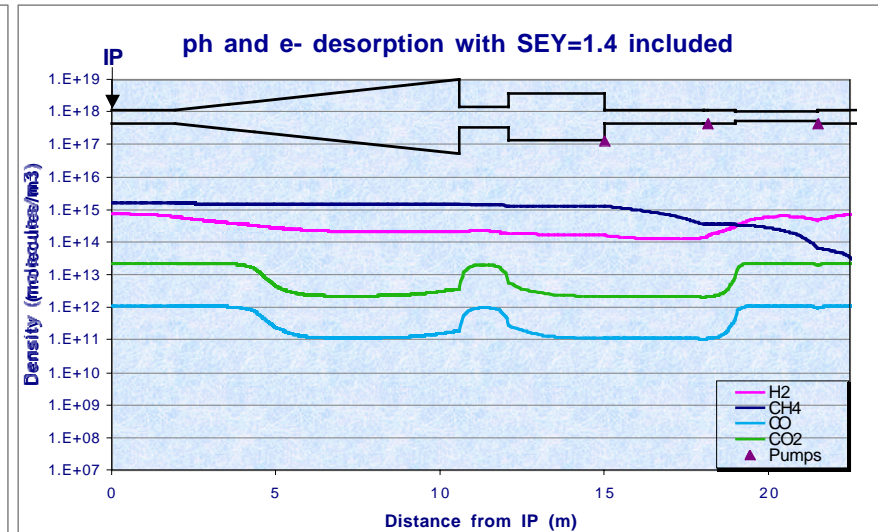
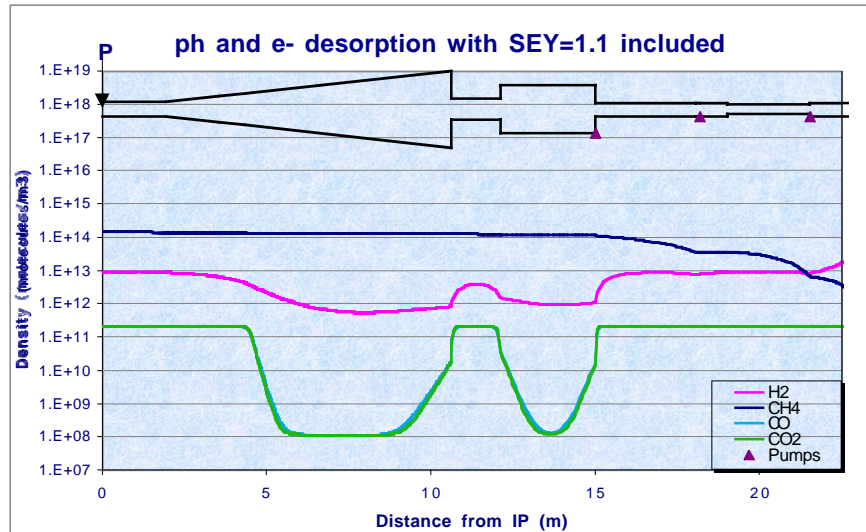
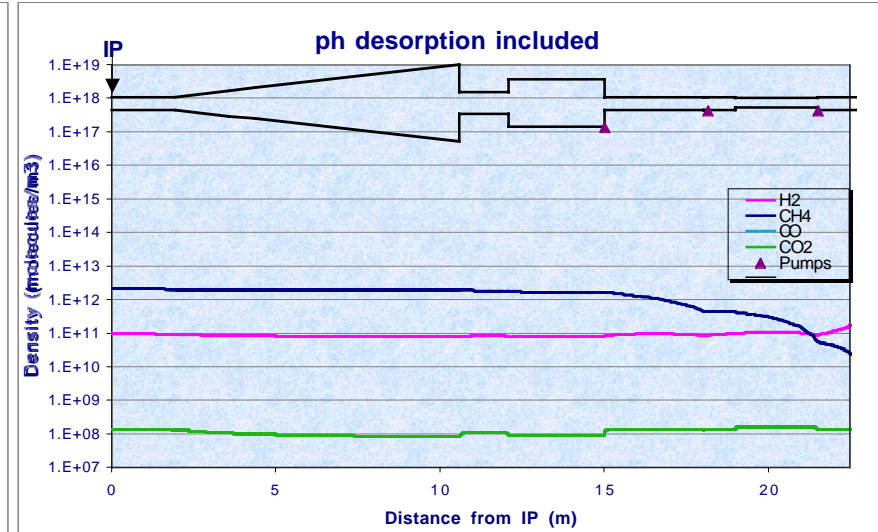
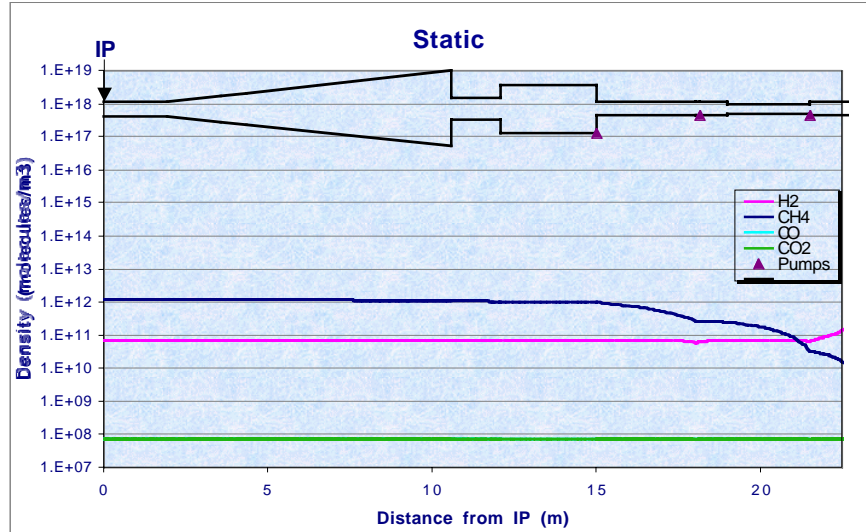
ATLAS beam pipe

Gas density (molecules/m³)



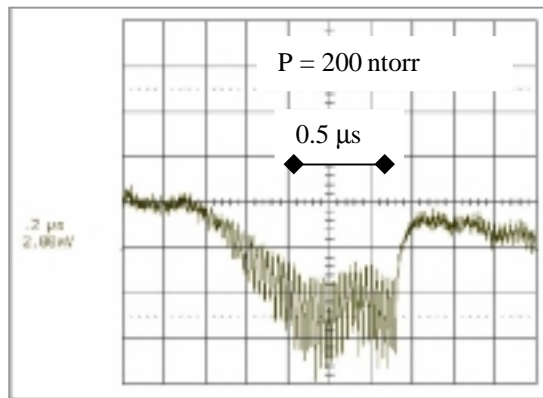
CMS-TOTEM beam pipe

Gas density (molecules/m³)



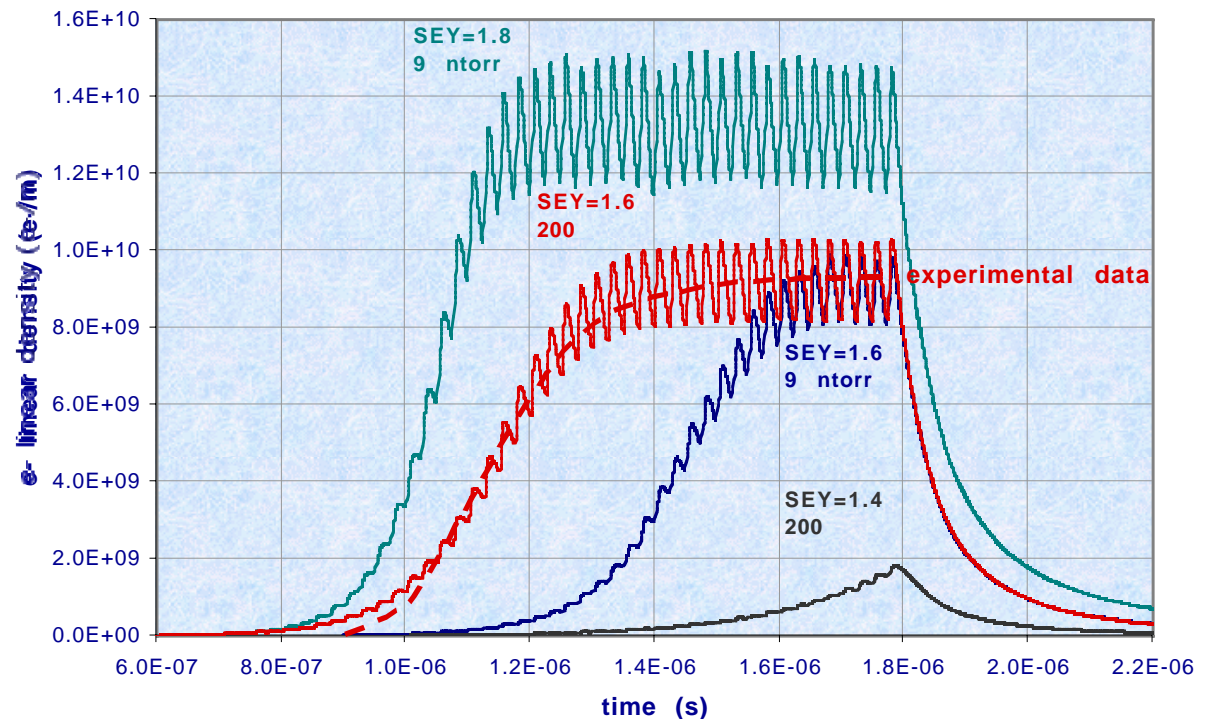
Code benchmarking

- e- cloud induced desorption main source of gas density → need of benchmarking of code ecloud (G. Rumolo, F. Zimmermann) to use it for predictive-quantitative estimations
- Benchmark against SPS pick-up measurements (M. Jimenez et al.)
- Primary source of electrons : gas ionisation
 - 72 bunches,
 - $8.3 \cdot 10^{10}$ protons/bunch,
 - 30 cm, 26 GeV bunches
 - Field free region
 - SPS-MBA geometry (r_H 76 mm r_V 17.5 mm)



Courtesy of M. Jimenez

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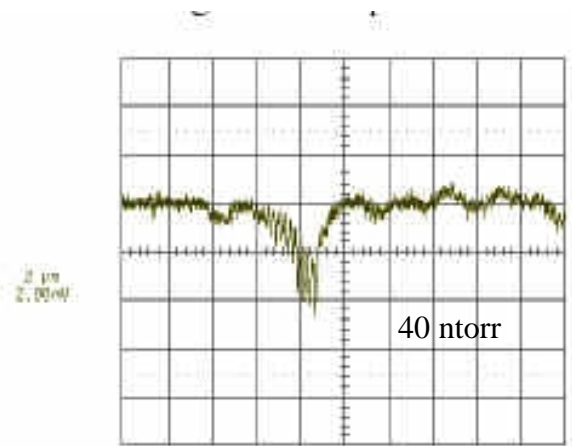


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Code benchmarking

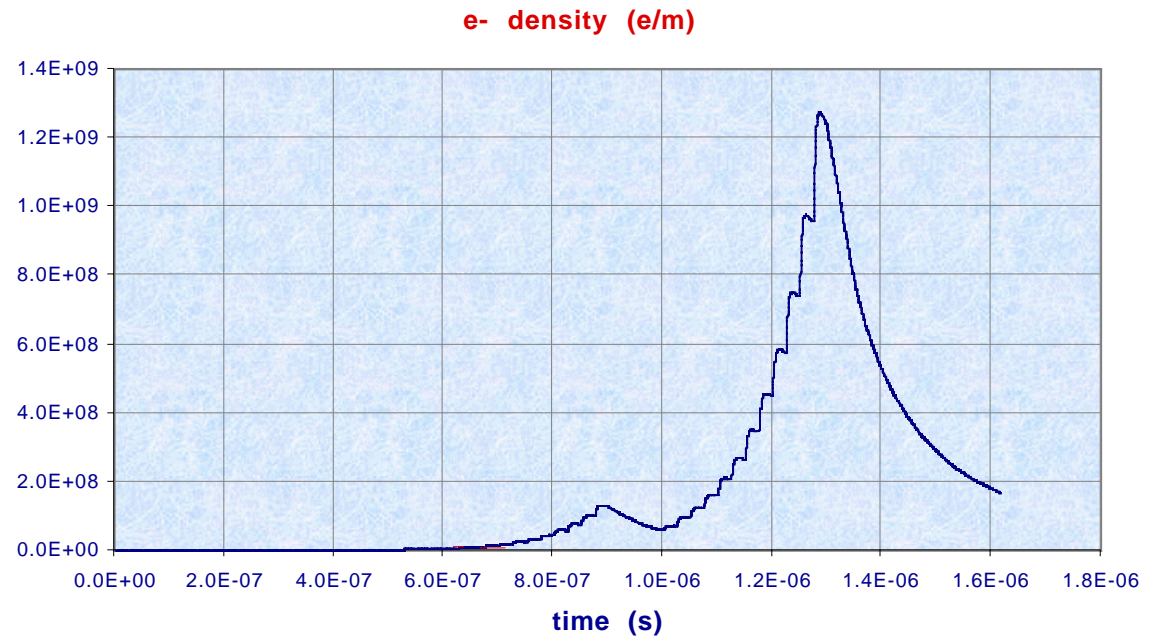
- 36 - 4 missing - 12 bunches,
- $8.3 \cdot 10^{10}$ protons/bunch,
- 30 cm, 26 GeV bunches
- Field free region
- SPS-MBA geometry (r_H 76 mm r_V 17.5 mm)

- Tests of missing bunches to suppress e- multipacting



Courtesy of M. Jimenez

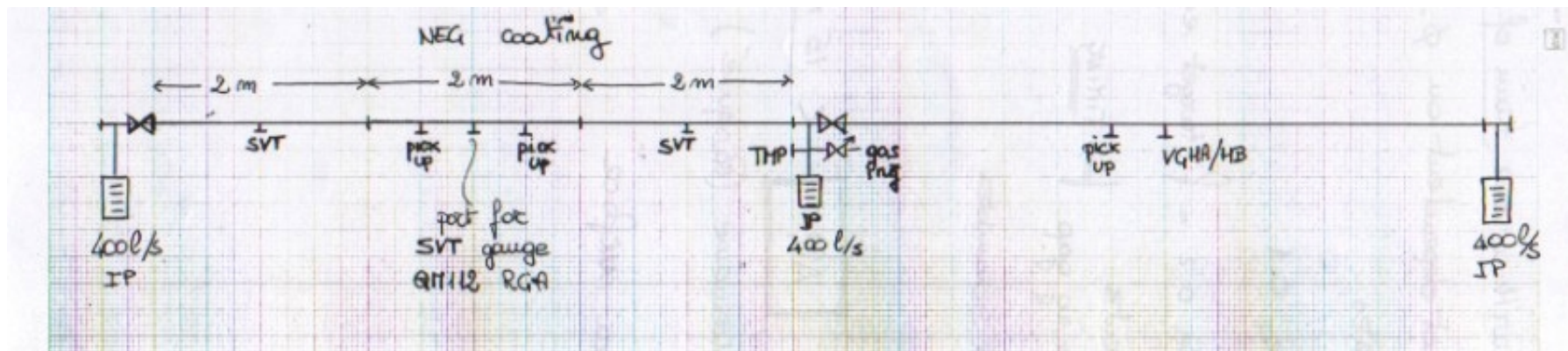
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NEG experiments in the SPS

- Field free region
- Φ 156 mm, Stainless Steel TiZrV NEG coated
- Stainless Steel reference chamber, not conditioned
- Pick-up and pressure measurements
 - LHC type beam
 - NEG activated at 200°C and CO saturated (same pressure as reference chamber)
 - Vented to air



Conclusions and future work

- The electron cloud has been studied for the different radii and with SEY typical of TiZrV NEG coating.
- Electron stimulated gas desorption (at nominal beam current) results the main contribution to the gas density.
- Effects on beam to be estimated.
- NEG experiments in the SPS to verify simulations are ongoing.
- Further benchmarking of e-cloud code necessary for quantitative estimations.